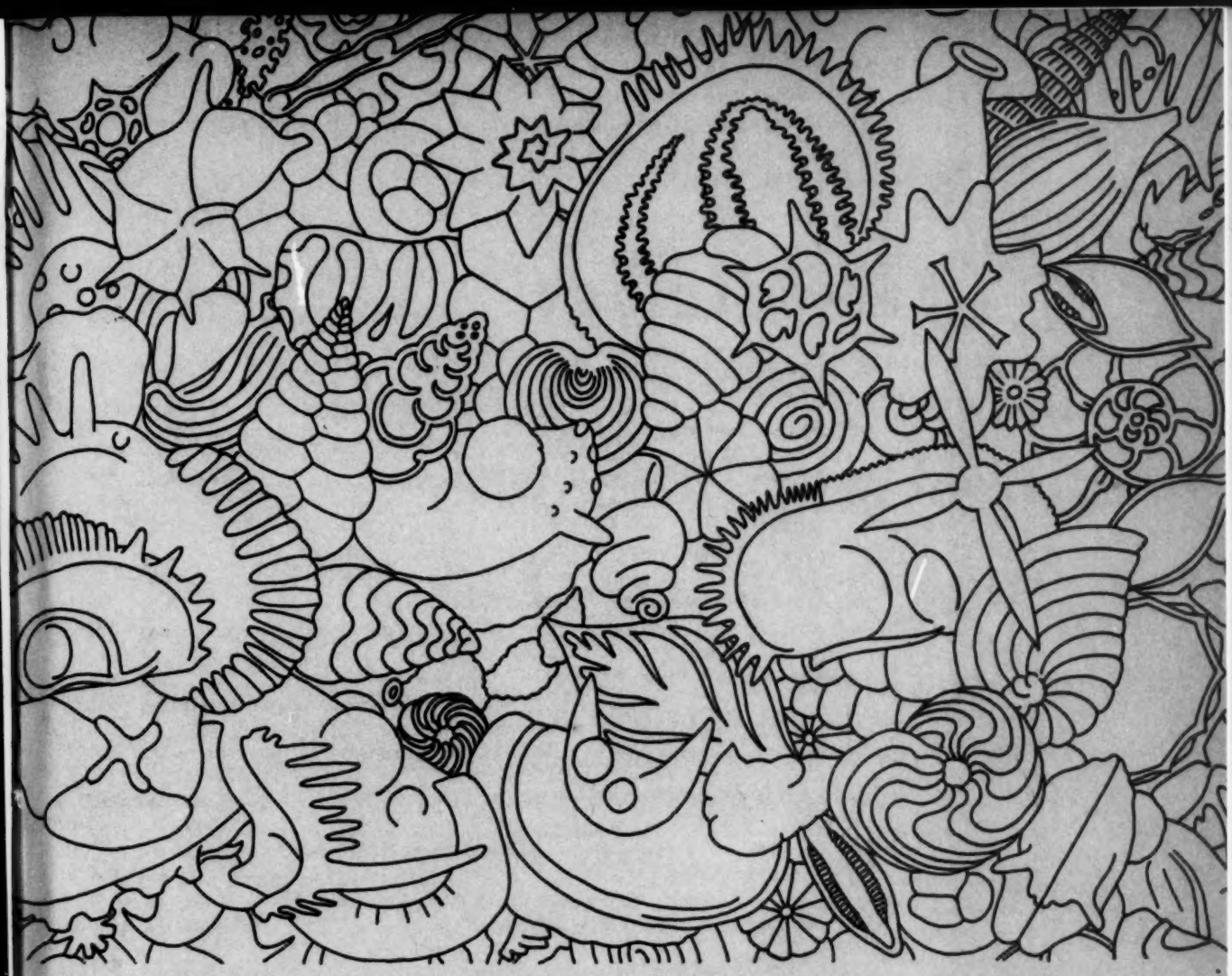

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Growing pains

MICROPALEONTOLOGY is now in its fourth year of existence. Since its beginning in 1955, it has grown in subscribers and in the number and quality of the papers published. When Volume 4 of MICROPALEONTOLOGY is closed this fall, it will contain about 460 pages of text and illustrative material, an increase of more than 7 per cent over the number of pages in Volume 3, and 9.5 per cent over the number of pages in Volume 2. It is estimated that Volume 5 must be increased to at least 500 pages if we are to avoid accumulating a backlog of papers. A rapid increase in the number of papers submitted for publication has made this problem very acute, and every effort to avoid delay must be made.

Unfortunately, an increase to 500 pages, or 19 per cent over the size of the quarterly in 1956, is going to add substantially to publication costs. The cost of the 7 per cent increase for 1958 is being absorbed by the Department of Micropaleontology, as is also the deficit for the preceding years. As MICROPALEONTOLOGY is not subsidized by any society or research fund, deficit financing by this Department cannot be continued indefinitely. We believe that the time has now come for the quarterly to become entirely self-supporting.

A subscription price of $10.00 per year would accomplish this end by the close of 1959. At the same time, the size of MICROPALEONTOLOGY could be increased sufficiently to insure prompt publication of the papers submitted to us. Under the circumstances, we feel that we have no alternative but to increase the price to $10.00 per year, beginning in January, 1959. We hope that all of our subscribers will understand the necessity for this step.

THE EDITORS

ABSTRACT: *In this paper, 128 species of foraminifera and twelve species of holothuroid sclerites from Jurassic rocks outcropping at Gebel Maghara, northern Sinai, are described and illustrated. Thirty-five species and two genera of foraminifera, and five holothuroid sclerites, are believed to be new. Sponge spicules from the Kimmeridgian are also illustrated but are not described. This study is primarily paleontological, but the stratigraphic value of these fossils is discussed, and the results of microfacies analyses of a number of indurated rocks in the succession are presented.*

Jurassic microfossils from Gebel Maghara, Sinai, Egypt

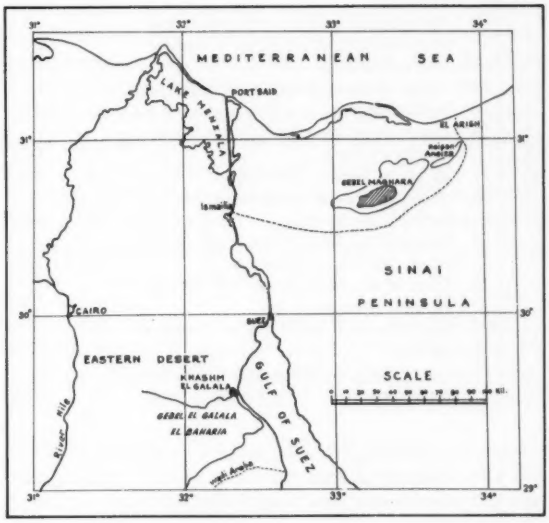
RUSHDI SAID AND M. G. BARAKAT
Cairo University
Cairo, Egypt

INTRODUCTION

Although it is now more than forty years since the discovery of Jurassic rocks in Sinai by Barthoux and Douvillé (1913), no systematic description of the microfossils of these rocks has ever been attempted. The Jurassic rocks of Egypt are known from two main outcrops: One is at Gebel Maghara in Sinai, where a succession some 2200 meters thick is known, and the other is at Khasm el Galala, some 70 kilometers south of Suez on the Egyptian side of the Gulf of Suez, where Bathonian rocks about 115 meters thick are reported. There are, in addition, a few scattered and relatively thin occurrences, to the south of these two main outcrops, that have recently been described.

The Gebel Maghara exposure is by far the most complete and the thickest Jurassic section in Egypt. The great Maghara Dome covers an area of approximately 400 square kilometers, and lies along the desert road from Ismailia on the Suez Canal to el-Arish on the Sinai Mediterranean coast (text-fig. 1). The broad outlines of the stratigraphy, structure, and macropaleontology of this area are discussed in the works of Douvillé (1916), Hume (1921), Moon and Sadek (1921), Barthoux (1922), Sadek (1925), and Arkell (1952).

The Maghara Dome has at its core a series of sandstones of Nubian facies, which are variously interpreted as belonging to the Triassic, the Liassic, or the Aalenian. These sandstones are followed by a succession of alternating sandstones, limestones, marls, shales, dolomites, and flint bands that attain a thickness of about 2200 meters. These beds yield faunas that are well correlated with those of western Europe, ranging in age from Bajocian to Kimmeridgian. The relationships of these deposits to the overlying Lower Cretaceous rocks are obscure, but

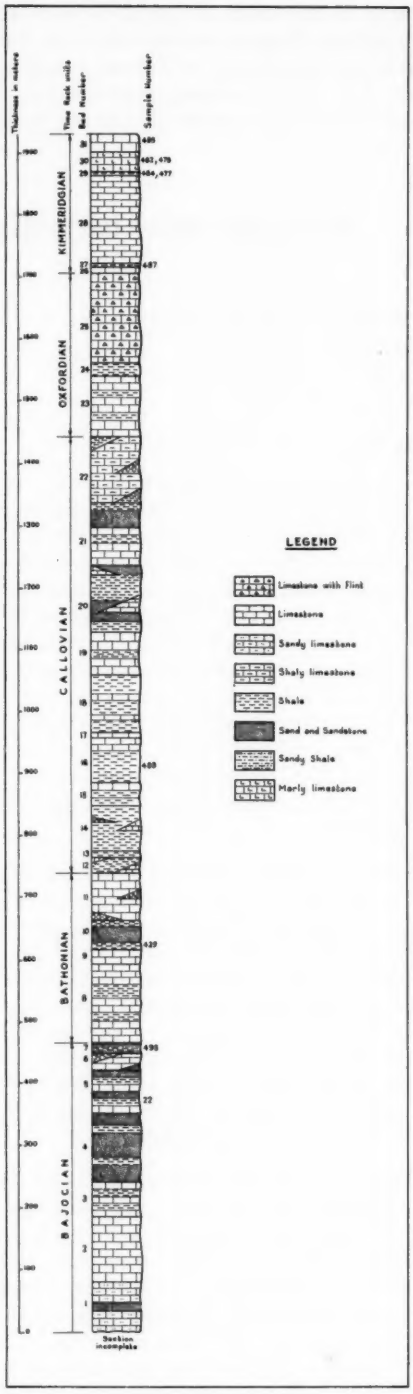


TEXT-FIGURE 1
KEY MAP SHOWING DISTRIBUTION OF THE JURASSIC IN EGYPT AND SINAI

the uppermost Jurassic rocks seem to be lacking. At Gebel Maghara, the Dogger and Malm succession proper consists of about 55 per cent limestone, 35 per cent shale, and 10 per cent sandstone.

A summary of a section measured at this locality by Haight and others in 1942 is given below. The tops of the time-rock units as they appear in this section represent the interpretations of the present authors, based on field work during the 1954–1955 season and on the faunal content. Text-figure 2 is a columnar section showing the position of the samples analyzed.

Time-rock unit	Bed no.	Description	Thickness in meters	Total thickness
Kimmeridgian	31	Chalky limestone	29	1901
	30	Marly limestone	31	1872
	29	Gray shale	5	1841
	28	Light gray limestone	139	1836
	27	Gray shale	5	1697
	26	White limestone	10	1692
Oxfordian	25	Limestone with flint bands	142	1682
	24	Gray to brown shale	22	1540
	23	Limestone, sometimes oolitic, with shale intercalations	95	1518
Callovian	22	Fossiliferous shaly limestone with thin stringers of shale	105	1423
	21	Limestone with bands of shale and sandstone	102	1318
	20	Alternating beds of shale and sandstone with thin stringers of fossiliferous limestone	105	1216
	19	Gray limestone with alternating beds of shale	68	1111
	18	Gray shale interbedded with thin limestone beds	93	1043
	17	Shaly to brown limestone	8	950
	16	Shale with thin bands of limestone, fossiliferous at top	73	942
	15	Alternating thin beds of shaly sandstone, shale and limestone	35	869
	14	Gray shale, fossiliferous, with stringers of limestone	70	834
	13	Banded gray shale with rounded nodules	10	764
	12	Gray shale with stringers of fossiliferous limestone 1 to 2 meters thick	24	754
Bathonian	11	Fossiliferous limestone with thin stringers of shale	78	730
	10	Alternating beds of shale and sandstone	46	652
	9	Dark gray limestone	23	606
	8	Dark gray limestone with alternating beds of fossiliferous limestone and shale	124	583
Bajocian	7	Alternating beds of shale and sandstone	17	459
	6	Dark gray fossiliferous limestone with thin stringers of shale and sandstone	25	442
	5	Alternating thin beds of flaggy limestone, shale and sandstone	70	417
	4	Brown sandstone and shale, sometimes fossiliferous, with thin beds of limestone	10	347
	3	Alternating beds of shale and limestone	55	238
	2	Dark gray bedded limestone, fetid in lower part, fossiliferous	104	183
	1	Compact to sandy limestone with a bed of variegated sandstone	79	79



TEXT-FIGURE 2

COLUMNAR SECTION SHOWING THE MAJOR SUBDIVISIONS AT GEBEL MAGHARA

MICROFOSSILS

Foraminifera are relatively rare in the Maghara Jurassic as compared with the Cretaceous or Tertiary formations of the same area. Most specimens are small and poorly preserved, and consequently are extremely difficult to find in washed samples. Most of the genera and species of foraminifera are restricted to a few relatively thin beds in this thick succession, and even then, enormous quantities of the rock must be washed before any sizable number of specimens can be extracted. By and large, the Kimmeridgian is relatively richer in foraminiferal species and individuals than the remainder of the section. It was not possible to separate any foraminifera from the Oxfordian, although thin sections of some of the harder rocks of this unit show tests of foraminifera.

Most of the species of foraminifera from the Egyptian Jurassic belong to the Lagenidae, although arenaceous forms are common, particularly in the upper Malm. On the whole, the Bajocian and Bathonian faunas are similar and are distinct from the Callovian and Kimmeridgian faunas. This observation is very interesting, as the Bathonian-Callovian boundary is one of the most difficult to establish in the field, and earlier workers usually lumped the two units together under the term "Bathonian-Callovian."

In addition to the foraminifera, a few other microfossil specimens have been found. These are sponge spicules and holothurian sclerites. Sclerites of holothuroidians have been reported repeatedly from Jurassic rocks throughout the world. According to Frizzell and Exline (1955), the Jurassic faunas are varied and conspicuous, and contain some fifty-two known "species," belonging to eighteen "genera" and seven "families." Of these forms, "ten genera appeared in the Jurassic for the first time, three became extinct and two are restricted to the Jurassic."

The nomenclature of these fragmental microfossils has caused the authors some difficulty. Many different forms of these sclerites may belong to one species, and, conversely, many similar forms may belong to different species. The present authors, recognizing the difficulty if not the impossibility of knowing the interrelationships of these various fragmentary remains, have accepted the utilitarian classification recently proposed by Frizzell and Exline (1955), which is based on the admittedly false assumption that different kinds of sclerites belong to distinct species.

Various holothuroid remains are found in both the Dogger and Malm of northern Sinai. The Dogger and Malm sclerites are well differentiated and distinct from each other. Sponge spicules, on the other hand, are found almost exclusively in the Kimmeridgian rocks. Morphological vernacular names have been adopted for the few sponge spicules extracted from the Jurassic rocks of Egypt.

DISTRIBUTION OF MICROFOSSILS

Of the forty species of foraminifera recorded from the Bajocian, the following are restricted to this unit: *Ammobaculites* cf. *cobbani*, *Astacolus inaequistriata*, *Astacolus matutina*, *Astacolus stilla*, *Citharina clathrata*, *Dentalina crenata*, *Dentalina turgida*, *Epistomina costifera*, *Frondicularia lignaria*, *Involutina aspera*, *Lenticulina acutiangulata*, *Lituola* sp., *Rectoglandulina tenuis*, and *Trochammina bartensteini*. Only one species, *Epistomina costifera*, was found in sample no. 495, from a bed supposed to be transitional between the Bajocian and the Bathonian. This species is known from the Dogger γ and δ in northwestern Germany (Bartenstein and Brand, 1937), which corresponds to the top of the Bajocian, according to Jeannet (1937). The assignment of a Bajocian age to this bed confirms the conclusions reached independently by Arkell (1952) on the basis of an analysis of the macrofaunal content.

The majority of the holothuroid sclerites (pl. 1, fig. 40a–d; pl. 6, fig. 13) found in the Bajocian are rods and hooks. There are, in addition, a few spired tables.

The Bathonian foraminifera are relatively scarce. Only thirty species are recorded from this unit. The fauna is close to that of the Bajocian, but the following species are restricted to this unit: *Cornuspira orbicula*, *Dentalina arbuscula*, *Haplophragmoides barthouxi*, *Lingulina cernua*, *Lingulina pupa*, *Nodosaria dolioligera*, *Nodosaria fontinensis*, *Nodosaria mitis*, *Nodosaria opalinii*, *Patellina douvillei*, *Quinqueloculina compressa*, *Rectoglandulina abbreviata*, *Rectoglandulina humilis*, *Spiroplectammina biformis*, and *Vaginulina legumen*.

Bathonian holothuroid sclerites (pl. 2, fig. 31) are abundant. They include, in addition to a few rods and hooks, an abundance of plates, spired tables, and wheels.

In the Callovian rocks, many new species of foraminifera appear, and the fauna is somewhat intermediate between that of the Dogger and that of the upper Malm. Arenaceous forms become abundant and constitute a substantial part of the fauna. There is an abundance of *Ammodiscoides magharaensis* and

other arenaceous forms. The Lagenidae, however, still make up the largest percentage of species and individuals in the fauna. The following species are known only from the Callovian: *Arenovirgulina aegyptiaca*, *Astacolus minuta*, *Discorbis dreheri*, *Involutina gaultina*, *Lenticulina tricarinella*, *Lingulina minuta*, *Reophax metensis*, *Trocholina transversarii*, and *Vaginulinopsis bartensteini*.

Callovian holothuroid sclerites (pl. 3, fig. 44) are very scarce. They are mostly in the form of rods and wheels.

The Kimmeridgian foraminiferal fauna is rich and varied. The number of species recorded from this unit is seventy-five, which is 61 per cent of the total fauna of the entire Jurassic succession of Maghara. The fauna is distinguished by an abundance of arenaceous forms, which constitute about 35 per cent of the species and individuals of this unit. The new genus *Paleogaudryina*, which appears first in small quantities in the Callovian, becomes quite abundant in the Kimmeridgian, together with several species of *Ammobaculites*, *Trochammina*, and *Reophax*. The following species occur only in the Kimmeridgian: *Ammobaculites elegantissima*, *Ammobaculites glaessneri*, *Ammobaculites magharaensis*, *Ammomarginulina pellucida*, *Annulina metensis*, *Bolivina bartensteini*, *Citharina flabelloides*, *Citharina inconstans*, *Conicospirillina planorbis*, *Conicospirillina trochoides*, *Dentalina torta*, *Dorothia terquemi*, *Epistomina depressa*, *Glomospira compacta*, *Glomospira jurassica*, *Lenticulina magharaensis*, *Lingulina dentaliniformis*, *Lituotuba* sp., *Miliammina* cf. *valendensis*, *Nodosaria nitidana*, *Nodosinella brandi*, *Nonion jurassicum*, *Rectoglandulina hofkeri*, *Rectoglandulina vulgata*, *Reophax barnardi*, *Reophax scorpiurus*, *Saracenaria cornucopiae*, *Saracenaria aegyptiaca*, *Trochammina depressula*, *Vaginulinopsis misrensis*, *Verneuilinoides attenuata*, *Verneuilinoides loeblichi*, and *Verneuilinoides minuta*.

A few holothuroid sclerites have been found in the Kimmeridgian (pl. 5, fig. 41). There is, however, a flood of sponge spicules (pl. 5, fig. 42). These are in the form of siliceous spheres and triaxons and calcareous polyaxons, tetraxons and triaxons that probably belong to *Pharetrone calcarea*.

Text-figure 3 shows the distribution of the characteristic microfossils recorded from the Maghara area. The zonal value of these fossils must remain uncertain until further studies of Jurassic exposures and subsurface occurrences in Egypt and nearby countries are made. Table 1 shows the distribution of species of foraminifera in the Jurassic rocks of Egypt.

ORIGIN OF THE FAUNA

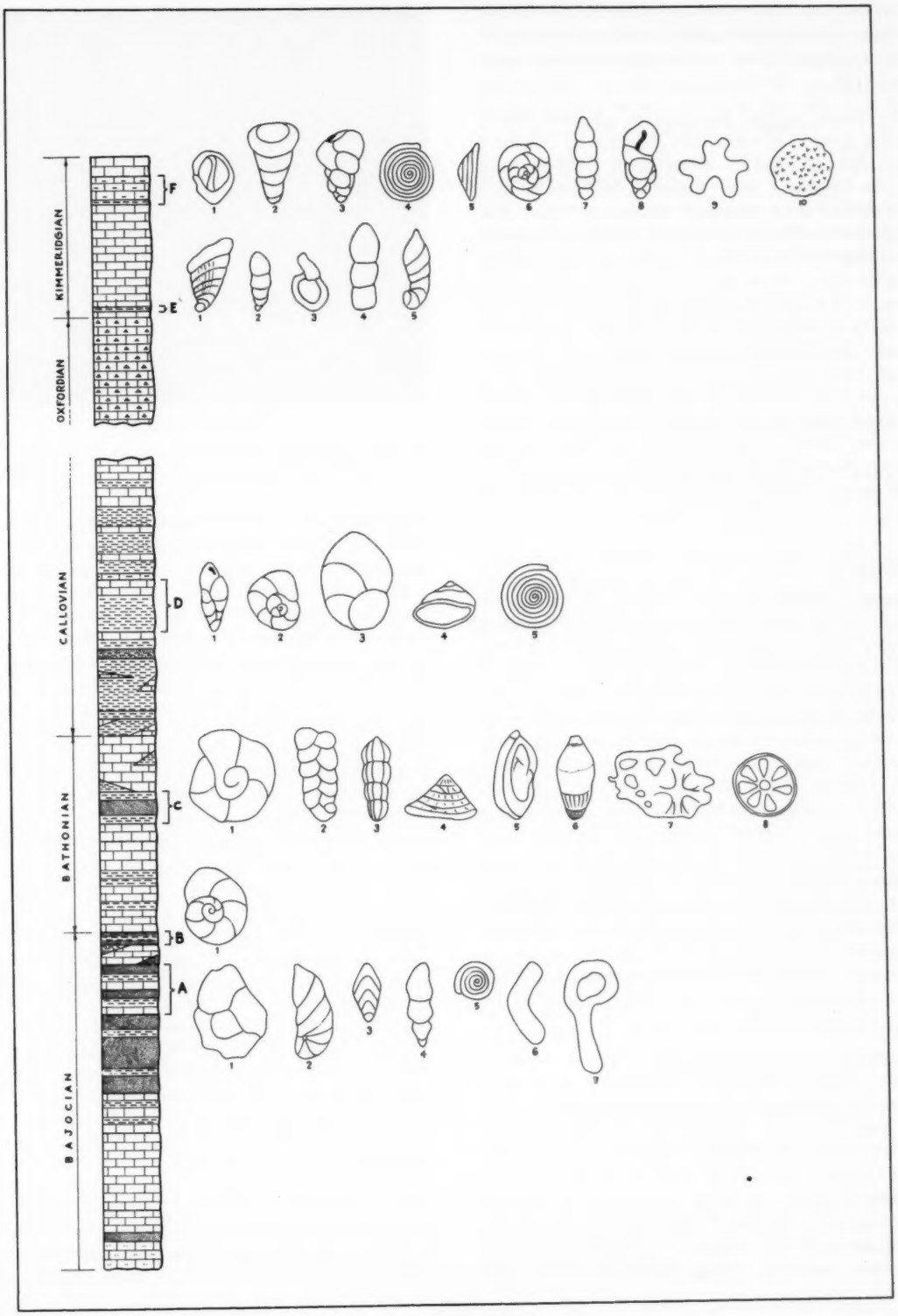
The Jurassic microfossils of Egypt are very similar to those described from central Europe, for example, by Roemer (1836), Schwager (1865, 1866, 1867), Terquem (1858–1877), Häusler (1890), Bartenstein and Brand (1937), and Mohler (1938). There are, however, a few notable differences. The Egyptian faunas differ in that the Lagenidae are less highly ornamented than those of the European faunas. The Bajocian Lagenidae are, with few exceptions small and smooth. There is such wide variation in the lagenid population of any one sample that it is difficult to trace the elaborate evolutionary lines which Barnard (1950) devised for the British Liassic Lagenidae. The genus *Trocholina* first appears in Egypt in the Callovian, rather than in the Oxfordian as in Europe. Only a few specimens that belong to this genus are known from Egypt so far. Henson (1948) described an abundant occurrence of this genus in comparable horizons in Israel. The Egyptian Kimmeridgian, although similar to that of Europe in having a sudden increase in arenaceous forms, is devoid of large Lituolidae such as *Pseudocyclammina* or *Choffatella*.

Remarkable similarity is also found between the Egyptian faunas and those recorded from the Jurassic of Somaliland (Macfadyen, 1935). This is an interesting observation, as it confirms the idea, recently proposed by Arkell (1952), that the Egyp-

TEXT-FIGURE 3

DISTRIBUTION OF CHARACTERISTIC MICROFOSSILS IN THE MAGHARA SECTION

A: 1, *Trochammina bartensteini;* 2, *Astacolus stilla;* 3, *Frondicularia lignaria;* 4, *Rectoglandulina tenuis;* 5, *Involutina aspera;* 6, *Stichopites mortenseni;* 7, *Achistrum bartensteini.* **B**: 1, *Epistomina costifera.* **C**: 1, *Haplophragmoides barthouxi;* 2, *Spiroplectammina biformis;* 3, *Lingulina pupa;* 4, *Patellina douvillei;* 5, *Quinqueloculina compressa;* 6, *Rectoglandulina abbreviata;* 7, *Priscopedatus aegyptiacus;* 8, *Theelia sinaiensis.* **D**: 1, *Arenovirgulina aegyptiaca;* 2, *Discorbis dreheri;* 3, *Lenticulina tricarinella;* 4, *Trocholina transversarii;* 5, *Ammodiscoides magharaensis.* **E**: 1, *Citharina flabelloides;* 2, *Lingulina dentaliniformis;* 3, *Lituotuba* sp.; 4, *Nodosaria nitidana;* 5, *Vaginulinopsis misrensis.* **F**: 1, *Glomospira compacta;* 2, *Nodosinella brandi;* 3, *Paleogaudryina magharaensis;* 4, *Ammodiscoides magharaensis;* 5, *Conicospirillina trochoides;* 6, *Epistomina depressa;* 7, *Rectoglandulina vulgata;* 8, *Verneuilinoides loeblichi;* 9, polyaxon (sponge spicule); 10, sphere (sponge spicule).



TEXT-FIGURE 3

tian Jurassic sea was connected with that of Arabia. This idea should substantially alter our paleogeographic reconstructions of that period in this part of the world.

The Egyptian Jurassic holothurian sclerites closely resemble those recorded from Europe by Münster (1843), Kuhn (1935), Bartenstein (1936), and Deflandre-Rigaud (1946). Indeed, the holothurians must have lived in one and the same basin. The presence in the Egyptian Upper Jurassic of sponge spicules that resemble closely, even to the method of preservation, those known from an equivalent horizon in the reef limestones of the Swabian Alps adds further evidence of the inferred connection between the Jurassic sea of Egypt and that of Europe. That these faunas so closely resemble those of Europe is in contrast to conditions in the Upper Cretaceous and Lower Tertiary of Egypt, whose faunas are more closely related to those of the Tampico Embayment and Central America (Said and Kenawy, 1956) than they are to those of Europe.

MICROFACIES

Systematic studies of thin sections of indurated Jurassic rocks from widely separated localities throughout the world have revealed the presence of distinctive problematic microfossils that seem to have great stratigraphic significance. The importance of these problematic forms has been noted by many of the earlier workers, and has recently been emphasized and elaborated upon by Lombard (1945), Colom (1955), Bronnimann (1955), Cuvillier (1951), and others. Most of these authors concentrated their studies on deep-sea or essentially pelagic sediments such as the fine-grained marly limestones or siliceous beds of the Middle and Upper Jurassic of the Alpine geosyncline. Study of similar beds found in the Far East and in the Western Hemisphere, for example in Cuba, has recently been undertaken. Intercontinental correlation based on these microfossils *incertae sedis* has proved to be remarkably successful.

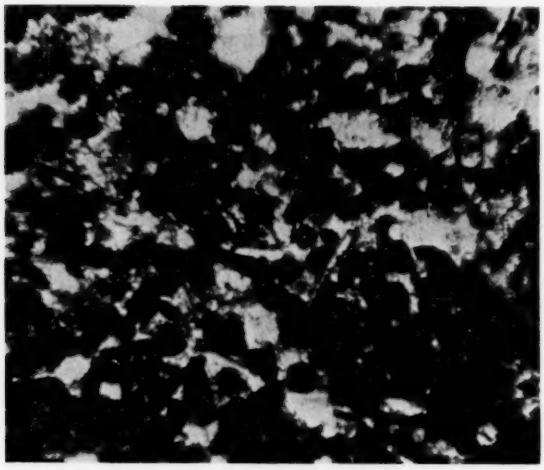
The Jurassic rocks of Egypt represent the platform deposits of the Tethys sea, and there is general agreement that these sediments were deposited away from deep-sea areas. Indeed, the continental mass was very similar to published isopach maps of this system (Shata, 1951). It is true, however, that the Egyptian Jurassic sea must have been a rapidly deepening one, especially near the shore, as the isopach lines are so extremely crowded that the 2200-meter isopach, along which Maghara lies, is no more than 100 kilometers from the supposed ancient shore line. This basin of deposition, although reasonably deep, must have been under the influence of terrigenous sedimentation. It is not surprising, therefore, that the true deep-sea biotope of the Mediterranean geosyncline did not extend to Egypt. Only those facies found in areas removed from the deep sea are to be expected in Egypt.

TEXT-FIGURE 4

Arcuate filaments of *Halobia(?)*, × 40, in marl from the upper Bajocian, sample no. 495.

The Maghara Bajocian and Bathonian microfacies are very similar, and it appears impossible, at least at present, to separate the two horizons on the basis of microfacies alone. Sedimentation during these two epochs resulted in the formation of yellowish marly limestones which at times become arenaceous, particularly at the higher horizons in the succession. In section, the arenaceous facies reveals the presence of highly angular quartz grains with ferruginous or marly cement. Angularity suggests first-cycle sedimentation. The marly facies is characterized by the presence, in some places, of enormous quantities of long, thin, arcuate fragments of *Halobia* (text-fig. 4) resembling those recently described by Colom (1955) from the western Mediterranean, which seem to characterize the Dogger in many parts of the Mediterranean geosyncline (see also the excellent photographs given by Cuvillier, 1951). This type of facies is frequently found at some distance from deep-sea areas.

The Callovian, Oxfordian and Kimmeridgian microfacies constitute a different type of facies, in which no Radiolaria nor tintinnids are found. The thin sandy beds of these units contain angular quartz



TEXT-FIGURE 5

Filaments of *Globochaete alpina* and zoospores, × 40, in marl from the upper Callovian, sample no. 464.

grains of smaller size than those found in the Dogger facies. The marly and limestone facies include, at certain levels, an abundance of algae of the types described by Lombard (1945) as *Globochaete alpina* and *Eothrix alpina(?)*. These fossils appear first in the Callovian, and have been reported from the Kimmeridgian of other Mediterranean countries. In thin section, the rocks of the Egyptian Malm reveal an intricate mixture of calcareous filaments together with a large number of rounded and bilobulate calcareous zoospores (text-fig. 5) that most probably belong to *Globochaete alpina*. Thalli of *Eothrix alpina* are probably present, as is indicated by the occurrence of characteristic Y-shaped objects in thin sections. In addition to these forms, there are some peculiar remains consisting of a large number of chaotically distributed filaments, some of which faintly show the branching described recently by Bronnimann (1955) as characteristic of *Lombardia angulata*. The true nature of these objects is, however, extremely difficult to determine.

In brief, study of the microfacies of the Jurassic rocks of Egypt has demonstrated that these sediments can be correlated with their counterparts in other Mediterranean regions. The Egyptian Jurassic does not belong to the pelagic biotope described from other parts of the Tethys area, but its sediments were deposited in a deepening basin that was under the influence of terrigenous sedimentation. The sediments must have been deposited in moderately deep waters. This conclusion is strengthened by the presence of sponge remains characteristic of deeper waters.

ACKNOWLEDGMENTS

The authors wish to acknowledge the great assistance graciously given by M. A. Basiouni in the preparation of the foraminiferal plates that accompany this paper. Thanks are also due to Dr. I. A. Farag for his help in the field.

SYSTEMATIC DESCRIPTIONS

Types of new species, and figured specimens of other forms, have been deposited in the collections of the United States National Museum, Washington, D. C.

Phylum PROTOZOA

Order FORAMINIFERA

Family ASTRORHIZIDAE

Genus RHABDAMMINA M. Sars, 1869

Rhabdammina aegyptiaca Said and Barakat, **new species**

Plate 4, figure 1

Test small, tubular, inflated in the middle portion; diameter of inflated part more or less double that of the tube; ellipsoidal in shape, tapering gradually at both ends of the tube; wall finely arenaceous with smooth surface; apertures at the open ends of the tube. Length 0.5 mm.; diameter of inflated part 0.25 mm.

The holotype is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Only three specimens of this species were found, all in the Kimmeridgian of Maghara.

Rhabdammina sp.

Plate 3, figure 1

Test free, cylindrical, wall very coarsely arenaceous, composed of sand grains and elongate foreign fragments; inflated in the middle; both ends of the tube short, parallel-sided, rounded in cross section; apertures formed by the open ends of the tube. Diameter of inflated part 0.27 mm.; diameter of end tubes 0.2 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai.

Family RHIZAMMINIDAE

Genus BATHYSIPHON M. Sars, 1872

Bathysiphon sp. 1

Plate 3, figure 2

Test free, cylindrical, tapering very gradually, often straight; wall arenaceous, smoothly finished; apertures terminal, at the open ends of the tube. Diameter of figured specimen 0.14 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Several specimens of this species are recorded from the Callovian of northern Sinai.

Bathysiphon sp. 2
Plate 4, figure 2

Test free, tubular, slightly tapering, slightly curved; wall arenaceous, with sand grains variable in size, smoothly finished; apertures at the open ends of the tube. This species seems to be similar to *Bathysiphon* sp. 1 from the Callovian of Maghara. Length 0.77 mm.; diameter 0.14 mm.

The figured specimen is from sample no. 485, Wadi Horma, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of Maghara.

Family SACCAMMINIDAE

Genus PROTEONINA Williamson, 1858

Proteonina difflugiformis (H. B. Brady)
Plate 1, figure 1; plate 3, figure 3; plate 4, figure 3

Proteonina difflugiformis (H. B. Brady). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 128, pl. 1A, fig. 1; pl. 1B, figs. 1–2; pl. 2A, fig. 1; pl. 2B, fig. 3; pl. 3, fig. 1; pl. 4, fig. 1; pl. 5, fig. 1; pl. 8, fig. 1a–d; pl. 10, fig. 1a–e; pl. 11A, fig. 1a–e.

Several specimens of this species, similar to those recorded by Bartenstein and Brand, are found in the Bajocian, Callovian and Kimmeridgian strata of Gebel Maghara. The specimens are flattened and somewhat oval, and the wall is coarsely arenaceous, with sand grains variable in size. The test is smaller than is typical, and the neck is distinct and rather long.

The figured specimens are from sample no. 22 (pl. 1, fig. 1), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 3), Gebel Ingbashi, north of Bir Maghara; and from sample no. 487 (pl. 4, fig. 3), Gebel Melha; all in northern Sinai.

Proteonina sp. 1
Plate 3, figure 4

Test free, compressed; wall very coarsely arenaceous, composed of large sand grains separated from each other by depressed meandering furrows; aperture circular, on a poorly developed neck. Diameter 0.3 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. This species differs from *Proteonina difflugiformis* (H. B. Brady) in being much compressed and in having a very coarse-grained test.

Proteonina sp. 2
Plate 4, figure 5

Test flattened, oval; wall coarsely arenaceous, with sand grains variable in size; periphery subacute; aperture simple, terminal, on a short neck.

The figured specimen is from sample no. 477, Wadi Imshash Rashed, Gebel Meleha, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Family HYPERAMMINIDAE

Genus HYPERAMMINA H. B. Brady, 1878

Hyperammina sp. 1
Plate 3, figure 5

Test free, elongate, thin, consisting of a small proloculum and a long, undivided second chamber; wall finely arenaceous, smoothly finished, transparent; aperture formed by the open end of the tube. Diameter 0.01 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Few specimens of this species were found in the Callovian of northern Sinai.

Hyperammina sp. 2
Plate 4, figure 6

Test elongate, consisting of a large proloculum and a long, slender, undivided tubular second chamber; wall finely arenaceous, very smoothly finished; aperture formed by the open end of the tube. Length 0.45 mm.; diameter 0.6 mm.

The figured specimen is from sample no. 485, Wadi Horma, Gebel Maghara, northern Sinai. Only three specimens of this species were found in the Kimmeridgian of Maghara.

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

Reophax barnardi Said and Barakat, **new species**
Plate 4, figure 7

Test elongate, slightly tapering; wall composed of agglutinated foreign material, very roughly finished; chambers uniserially arranged, inflated, as many as three in number, increasing gradually in size as added; sutures indistinct, faintly depressed; periphery rounded; aperture terminal, on a short, protruding neck. Length 0.6 mm.; diameter of upper part 0.25 mm.

This species differs from *Reophax scorpiurus* Montfort in having a roughly finished and more tapering test and in having the chambers increasing in size more rapidly.

The holotype is from sample no. 478, along Wadi Imshash Rashed, northern Sinai. Several specimens of this species were found in the Kimmeridgian of Maghara.

Reophax cf. **metensis** Franke
Plate 3, figure 6

Reophax metensis FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 19, pl. 1, fig. 17a–b.

Test free, of medium size, elongate, slightly tapering, consisting of four inflated chambers in a linear series, increasing gradually in diameter as added; early chambers as long as broad, later chambers becoming longer than broad; sutures distinct, depressed, straight; wall coarsely arenaceous; aperture terminal, at the end of a short, protruding neck.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Several specimens that seem to belong to this species are recorded from the Callovian of Northern Sinai.

Reophax scorpiurus Montfort
Plate 4, figure 9

Reophax scorpiurus Montfort. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 19, pl. 1, fig. 18.

Test free, elongate, tapering very slightly, consisting of three distinct, slightly inflated chambers in a linear series; sutures distinct, depressed, straight; wall coarsely arenaceous, surface rough; aperture simple and terminal.

The figured specimen is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of Maghara.

Genus NODOSINELLA H. B. Brady, 1876

Nodosinella brandi Said and Barakat, **new species**
Plate 4, figure 11a–b

Test free, straight, rounded in cross section; chambers disc-shaped, arranged uniserially, somewhat distinct, increasing in size as added; wall finely arenaceous, thick; aperture terminal, large, as wide as the diameter of the last chamber. Length 0.33 mm.; diameter 0.25 mm.

This species is quite distinct. It is characterized by its tapering test, thick wall and wide aperture.

The holotype is from sample no. 482, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A few specimens of this species are recorded from the Kimmeridgian of northern Sinai.

Family TOLYPAMMINIDAE

Genus INVOLUTINA Terquem, 1862

Involutina aspera Terquem
Plate 1, figure 3

Ammodiscus asper (Terquem). – BARNARD, 1949, Geol. Soc. London, Quart. Jour., vol. 105, p. 351, text-fig. 1a.

A few specimens of this species are recorded from the Egyptian Jurassic rocks. Our specimens are smaller than is typical, and possess fewer whorls, but they exhibit the slight overlapping of the whorls and the variation in the shape of test to a slender elongate variety discussed by Barnard.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Involutina gaultina (Berthelin)
Plate 3, figure 8

Ammodiscus gaultinus BERTHELIN, 1880, Soc. Géol. France, Mém., ser. 3, vol. 1, p. 19, pl. 1, fig. 3a–b.

Test free, discoid, consisting of a proloculum and a long, tubular, undivided second chamber arranged in about four irregularly coiled whorls, increasing gradually in diameter; periphery rounded; spiral suture slightly depressed; wall very finely arenaceous; aperture at the open end of the tubular chamber.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens of this species were found in the Callovian of Gebel Maghara.

Involutina magharaensis Said and Barakat, **new species**
Plate 1, figure 2; plate 4, figure 12

Test composed of a long, undivided tubular chamber closely coiled; coils strongly overlapping, gradually increasing in size; wall finely arenaceous with much cement, smooth; aperture formed by the open end of the tube, crescentic because of the overlapping of coils. Diameter 0.4 mm.

Many specimens of the microspheric form are very slightly conical in the initial part of the test, and the species may therefore belong to *Ammodiscoides*. This species differs from *Involutina aspera* Terquem in having a more closely coiled test and in having the earlier part tightly coiled and slightly conical.

The holotype is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai (pl. 1, fig. 12). The figured paratype is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai (pl. 4, fig. 12). A few specimens of this species are known from the Bajocian, but the species is abundant in the Kimmeridgian of Egypt.

Genus AMMODISCOIDES Cushman, 1909

Ammodiscoides magharaensis Said and Barakat, **new species**
Plate 3, figure 7a–c; plate 4, figure 8a–c

Test free, small, planispiral, composed of a proloculum followed by a long, undivided, close-coiled, tubular second chamber; coils arranged in a slightly conical

spire, forming seven complete, slightly overlapping whorls; wall finely arenaceous; periphery subacute; aperture formed by the open end of the tube. Diameter of holotype 0.35 mm.

This species is characterized by its cone-shaped test, which does not exactly fit the characteristics of the genus *Ammodiscoides*, and our specimens may, in this respect, represent the megalospheric form only. A study of a large number of specimens showed that this character seems to be universal, although a certain degree of planispirality seems to appear in the last whorl only.

The holotype is from sample no. 489, Gebel Ingbashi, north of Bir Maghara (pl. 3, fig. 7). Paratype from sample No. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai (pl. 4, fig. 8). This species is found in great abundance in the Callovian and Kimmeridgian strata of Gebel Maghara, and seems to be of stratigraphic value, particularly when present in flood.

Genus Glomospira Rzehak, 1888

Glomospira compacta Said and Barakat, **new species**
Plate 4, figure 14

Test free, composed of a proloculum and a long, undivided, tubular second chamber winding about its earlier coils in various planes; coils increasing greatly in size as added; wall finely arenaceous; aperture simple, at the open end of the tube. Diameter 0.2 mm.

This species can be distinguished from the following one by the fact that it is more globular and that its coils increase in size as added.

The holotype is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. This species is frequent in the Kimmeridgian of northern Sinai.

Glomospira jurassica Said and Barakat, **new species**
Plate 4, figure 15

Test small, composed of a proloculum and a long, undivided, tubular second chamber winding about its earlier coils in various planes; wall finely arenaceous, surface smooth; aperture simple, at the open end of the tube. This species differs from *Glomospira gordialis* (Parker and Jones) in having a rougher exterior and a more elongate outline of the test, and in having the coils more winding.

The holotype is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai.

Genus Lituotuba Rhumbler, 1895

Lituotuba sp.
Plate 4, figure 4

Test small, consisting of a proloculum and a long, undivided second chamber; early portion irregularly coiled, later uncoiling; uncoiled part small and thin; wall finely arenaceous; aperture at the end of the tube.

The figured specimen is from sample no. 487, Gebel Meleha, northern Sinai. Only three specimens of this species were found in the Kimmeridgian of northern Sinai.

Family LITUOLIDAE

Genus Haplophragmoides Cushman, 1910

Haplophragmoides barthouxi Said and Barakat, **new species**
Plate 2, figures 1, 4

Test free, of medium size, planispirally coiled, partially evolute, with a central umbilicus, sides depressed, periphery subacute; chambers distinct, eight to ten in the adult coil, inflated, increasing gradually in size as added; sutures distinct, depressed; wall finely arenaceous; aperture a low opening at the base of the last-formed chamber. Diameter of holotype 0.5 mm.; thickness 0.1 mm.

This species differs from *Haplophragmoides glabra* Cushman and Waters in having a more evolute last coil and in having a smoothly finished test.

The holotype and paratype are from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

Haplophragmoides sp.
Plate 4, figure 16

Test free, of medium size, planispirally coiled, involute; periphery rounded; chambers increasing in size as added, about seven in the last whorl; sutures faintly distinct, slightly depressed; wall arenaceous, surface smooth; aperture a low, depressed opening at the base of the last chamber.

The figured specimen is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Only a few fragmental specimens were found in the Kimmeridgian of Maghara.

Genus Ammomarginulina Wiesner, 1931

Ammomarginulina pellucida Said and Barakat, **new species**
Plate 4, figure 18a–b

Test free, flattened; periphery acute; early portion close-coiled, composed of about six chambers; uniserial portion long, also consisting of about six chambers; chambers of uniserial part low, increasing very slightly as added; sutures of the coiled part obscure, those of the uniserial portion slightly depressed; wall arenaceous, smoothly finished, with much cement, somewhat transparent; aperture slit-like, terminal. Length 0.5 mm.; diameter of planispiral part 0.2 mm.

This species differs from *Ammomarginulina infrajurensis* (Terquem) in being much more slender and in having a smoothly finished test and a long uniserial portion.

The holotype is from sample no. 485, along Wadi Horma, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of Maghara.

Genus AMMOBACULITES Cushman, 1910

Ammobaculites cf. **cobbani** Loeblich and Tappan
Plate 1, figure 4

Ammobaculites cobbani LOEBLICH AND TAPPAN, 1950, Jour. Pal., vol. 24, p. 41, pl. 11, figs. 9–13.

Specimens that may be referred to this species are recorded from the Bajocian of Maghara. Our specimens are smaller than those described from the American Pepper shale. They have a well developed planispiral portion, a narrower umbilicus, a less lobulate periphery, and only one chamber in the uniserial portion.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Ammobaculites elegantissima Said and Barakat, **new species**
Plate 4, figure 19a–b

Test small; early portion coiled, umbilicate, consisting of six chambers, later portion uncoiling; chambers of uniserial part inflated, rounded in cross-section, arcuate, longer than broad, about four in number; sutures depressed in the uniserial part, becoming horizontal only after the first chamber; wall finely arenaceous, smoothly finished; aperture slit-like, terminal, on a slightly protruding neck. Length 0.35 mm.; diameter of planispiral part 0.14 mm.; diameter of uniserial part 0.1 mm.

This species is quite distinct. It is small for the genus, and has an umbilicate early part and long, enveloping chambers in the uniserial part.

The holotype is from sample no. 487, Gebel Meleha, district of Maghara, northern Sinai.

Ammobaculites fontinensis (Terquem)
Plate 2, figure 2; plate 3, figure 9

Ammobaculites fontinensis (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 127, pl. 12, fig. 25. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 186, pl. 5, fig. 79a–b; pl. 6, fig. 43; pl. 8, fig. 37a–d; pl. 10, fig. 44; pl. 11B, fig. 27; pl. 12A, fig. 21a–b; pl. 13, fig. 22.

Test small, periphery bluntly rounded, early portion planispirally coiled, later chambers in a rectilinear series; chambers numerous and low in the early portion; uniserial chambers slightly larger, about equal in height and breadth, rounded in cross section, last chamber tapering slightly to the aperture; sutures distinct, straight, depressed; wall coarsely arenaceous; aperture terminal, rounded; color brownish.

This species differs from *Ammobaculites polythalamus* Loeblich in having a coarser exterior and fewer chambers in the uniserial part. Our specimens have a smaller umbilicus than those recorded by Bartenstein and Brand (1937).

The figured specimens are from sample no. 429 (pl. 2, fig. 2), Gebel Somor, northwest of Bir Maghara; and from sample no. 489 (pl. 3, fig. 9), Gebel Ingbashi, north of Bir Maghara; both in northern Sinai. A few specimens of this species were found in the Bathonian and Callovian of Sinai.

Ammobaculites glaessneri Said and Barakat, **new species**
Plate 4, figures 20, 22

Test free, elongate, cylindrical; chambers numerous, about five or six in the early coiled portion, followed by about four inflated uniserial chambers; sutures distinct, depressed, straight; wall coarsely arenaceous; last chamber drawn out into a short neck, upon which the simple terminal aperture is situated. Length 0.95 mm.; diameter of planispiral part 0.5 mm.; diameter of uniserial part 0.4 mm.

This species is distinguished by the fact that the diameter of the uniserial part is very slightly smaller than that of the early coiled part. The species differs from *Ammobaculites agglutinans* (d'Orbigny) in having a more flattened planispiral part and longer uniserial chambers.

The holotype and paratype are from sample no. 487, Gebel Meleha, district of Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of Maghara.

Ammobaculites magharaensis Said and Barakat, **new species**
Plate 4, figure 21a–b

Test free, elongate, early portion close-coiled, umbilicate, later becoming uniserial; chambers numerous, about six in the early coiled part, about three in the uniserial part; chambers of uniserial part increasing rapidly in size as added, oval in cross section; periphery subrounded; wall coarsely arenaceous; aperture terminal and slit-like. Length 0.75 mm.; diameter of planispiral part 0.26 mm.; diameter of uniserial part 0.3 mm.

This species differs from *Ammobaculites glaessneri* Said and Barakat in having a coarser exterior, a depressed uniserial part, a distinct umbilicus in the early part, and rapidly enlarging chambers.

The holotype is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species are recorded from the Kimmeridgian of Maghara.

Genus BULBOBACULITES Maync, 1952

Bulbobaculites sp.
Plate 3, figure 10

Test free, of medium size, early portion close-coiled, streptospiral, later uniserial, rounded in cross section; early portion somewhat globular, involute, slightly larger in diameter than the uniserial part; chambers numerous, as many as four in number in the uniserial part, cylindrical, as long as broad; wall coarsely arenaceous, with sand grains variable in size; sutures straight, slightly depressed, especially at the margins, producing obvious constrictions in the uniserial part; aperture terminal, simple.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens of this species are recorded from the Callovian of northern Sinai. The presence of this genus in the Egyptian Callovian extends its range to the Jurassic. It was previously considered to be restricted to the Upper Cretaceous (Maync, 1952).

Genus LITUOLA Lamarck, 1804

Lituola sp.
Plate 1, figure 5

Test planispiral, later portion uncoiling, interior labyrinthic; wall arenaceous, with much cement; aperture terminal, multiple. Diameter of planispiral part 0.25 mm.

This species is characterized by having a somewhat thickened planispiral part and a multiple aperture that is slightly everted. The figured specimen is etched to show the laryrinthic interior.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens were found in the Bajocian of Maghara.

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina biformis (Parker and Jones)
Plate 2, figure 3

Spiroplectammina biformis (Parker and Jones). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 183, pl. 2B, fig. 39.

Test free, small, compressed, early portion distinctly coiled, later biserial, periphery bluntly rounded; biserial chambers increasing gradually in height; sutures faintly distinguishable; wall finely arenaceous; aperture at the base of the last-formed chamber.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species are recorded from the Bathonian of Gebel Maghara.

Family VERNEUILINIDAE

Genus VERNEUILINOIDES Loeblich and Tappan, 1949

Verneuilinoides attenuata Said and Barakat, **new species**
Plate 4, figure 23a–b

Test free, tapering, triserial, subtriangular in section; periphery rounded; chambers globular, as high as broad, increasing rapidly in size as added, so that almost one-third of the test consists of the last whorl; sutures distinct, depressed; wall finely arenaceous, very smoothly finished; aperture loop-shaped, at the base of the last-formed chamber. Length 0.5 mm.; diameter 0.25 mm.

This species differs from the following forms in having the last three chambers highly inflated and in having a more elongate and greatly depressed aperture.

The holotype is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of northern Sinai.

Verneuilinoides loeblichi Said and Barakat, **new species**
Plate 4, figure 24a–b

Test free, tapering, subtriangular in section; periphery rounded; chambers globular, overhanging, as high as broad, increasing rapidly and progressively in size as added; sutures distinct, depressed; wall finely arenaceous, surface smooth; aperture an arch at the base of the last-formed chamber. Length 0.33 mm.; diameter 0.2 mm.

This species differs from *Verneuilinoides tryphera* Loeblich and Tappan in having a more smoothly finished test and in having more globular, overhanging chambers.

The holotype is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Verneuilinoides minuta Said and Barakat, **new species**
Plate 4, figure 25a–b

Test small, triserial, subtriangular in section, composed of four whorls; chambers increasing rapidly and progressively in size as added, those of the last whorl very well developed and comprising about one-half of the length of the test, broader than high; sutures distinct, slightly depressed; wall arenaceous; aperture small, loop-shaped, at the base of the last-formed chamber.

This species differs from *Verneuilinoides attenuata* Said and Barakat in having a subtriangular cross section, a more regular arrangement of chambers, and a smaller aperture.

The holotype is from sample no. 484, along Wadi Imshash Rashed, northern Sinai. A few specimens of this species were found in the Kimmeridgian of northern Sinai.

Verneuilinoides sp.
Plate 3, figure 11a–b

Test free, slightly elongate, triserial throughout, earlier part somewhat triangular in cross section; chambers inflated, distinct, three making up each whorl, increasing greatly in size as added, the last whorl forming about one-third of the entire test; sutures depressed; wall arenaceous, smoothly finished; aperture loop-shaped, at the base of the inner margin of the last-formed chamber. Diameter 0.2 mm.; length 0.35 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Only two specimens of this species were found in the Callovian in northern Sinai.

Genus **Paleogaudryina** Said and Barakat, **new genus**

Genotype: *Paleogaudryina magharaensis* Said and Barakat, n. sp.

Definition: Test similar to *Gaudryina*; early chambers triserial, later portion biserial; wall arenaceous; aperture loop-shaped, virguline, extending along the apertural face.

This genus differs from *Gaudryina* d'Orbigny, 1839, in having a virguline aperture rather than "a transverse slit at or near the base of the last septal face." The genotype of *Gaudryina*, *Gaudryina rugosa* d'Orbigny, has a definite slit-like aperture that runs along the base of the last chamber, and thus the forms with virguline apertures must have a new name. The following previously described species seem to belong to *Paleogaudryina*: *Gaudryina bukowiensis* Cushman and Glazewski, *Gaudryina althi* Cushman and Glazewski, *Gaudryina jurassica* Cushman and Glazewski, *Gaudryina hawkinsi* Cushman, and *Gaudryina subcretacea* Cushman. It is interesting to note that all of these species are among the oldest recorded forms of *Gaudryina*.

Paleogaudryina magharaensis Said and Barakat, **new species**
Plate 3, figure 42a–b; plate 4, figures 33a–c, 36a–c

"*Gaudryina*" sp., Said and Barakat, 1957, Micropaleontology, vol. 3, no. 1, p. 42, pl. 1, fig. 17a–b.

Test small, elongate, tapering, greatest breadth near the apertural end; earlier triserial part comprising one-third of the entire test, triangular in section; later biserial part forming the greater portion of the test, subrectangular in section; chambers numerous, increasing gradually in size as added; sutures distinct, depressed, more or less horizontal; wall arenaceous, smoothly finished; aperture elongate, loop-shaped, extending along the apertural face. Length 0.33 mm.; breadth 0.2 mm.

This species differs from *Gaudryina foeda* (Reuss) in having a smoother wall and a large triserial part, and in the apertural characters. It differs from *Gaudryina bukowiensis* Cushman and Glazewski in being much smaller and in having a larger biserial part and a less flaring biserial portion.

The holotype is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Paratypes are from sample no. 478 (pl. 4, fig. 33), and from sample no. 489 (pl. 3, fig. 42), Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens were found in the Callovian of Maghara. This species occurs in large numbers, however, in the Kimmeridgian of this area, from which the holotype was obtained.

Family VALVULINIDAE

Genus **Arenovirgulina** Said and Barakat, **new genus**

Genotype: *Arenovirgulina aegyptiaca* Said and Barakat, n. sp.

Definition: Test elongate, more or less compressed, fusiform; chambers arranged biserially about an elongate twisting axis; wall arenaceous, smoothly finished; aperture elongate, loop-shaped, with a valvular tooth.

Arenovirgulina aegyptiaca Said and Barakat, **new species**
Plate 3, figure 38a–b

Test small, free; chambers arranged biserially along a slightly twisting axis, moderately inflated; early chambers small, somewhat obscure, increasing rapidly in length and breadth as added; periphery rounded; sutures distinct, slightly depressed; wall arenaceous, smoothly finished; surface smooth; aperture elongate, loop-shaped, on the apertural face of the final chamber. Length 0.23 mm.; breadth of upper part 0.14 mm.

The holotype is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai.

This genus seems to have developed along parallel lines with the calcareous genus *Virgulina* d'Orbigny, 1826, known also from the Jurassic. The characters of this genus are obviously those of the family Valvulinidae. Its presence in the Jurassic makes it the oldest representative genus in this family.

Genus Marssonella Cushman, 1933

Marssonella cf. **oxycona** (Reuss)
Plate 3, figure 12a–b; plate 4, figure 17

Gaudryina oxycona Reuss, 1860, Akad. Wiss. Wien, Math.-Naturw. Kl., Sitzber., vol. 40, p. 229, pl. 12, fig. 3.

A number of specimens that seem to belong to this species are recorded from the Callovian and Kimmeridgian of Sinai. Our specimens differ from forms recorded from the Cretaceous by other authors in being smoothly finished and much smaller, and in having a depressed top.

The figured specimens are from sample no. 489 (pl. 3, fig. 12), Gebel Ingbashi, north of Bir Maghara; and from sample no. 478 (pl. 4, fig. 17), along Wadi Imshash Rashed, Gebel Maghara, northern Sinai.

Genus DOROTHIA Plummer, 1931

Dorothia terquemi Said and Barakat, **new species**
Plate 4, figure 38a–b

Test small, elongate, about two and one-half times as long as broad, compressed, periphery truncate, biserial portion making up the entire test; chambers indistinct, of rather uniform size throughout, rectangular in shape; sutures distinct, slightly depressed, nearly at right angles to the vertical axis; wall finely arenaceous; aperture an arched opening at the base of the inner margin of the last-formed chamber. Length 0.5 mm.; diameter 0.2 mm.

This species resembles *Dorothia principiensis* Cushman and Bermudez except for the less lobulate periphery and rectangular chambers.

The holotype is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species are recorded from the Kimmeridgian of northern Sinai.

Family SILICINIDAE

Genus ANNULINA Terquem, 1862

Annulina cf. **metensis** Terquem
Plate 4, figure 13

Annulina metensis Terquem. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 129, pl. 4, fig. 11a–b; pl. 5, fig. 3.

Test discoidal, compressed, depressed centrally; wall finely arenaceous or siliceous, surface smooth. This form is most probably not a foraminifer. It is here recorded because it is found to have a limited stratigraphic range and seems to have considerable zonal value. It is also here recorded among the holothuroids of Gebel Maghara (see below).

The figured specimen is from sample no. 482, along Wadi Imshash Rashed, northern Sinai. (See also pl. 6, fig. 12.)

Genus MILIAMMINA Heron-Allen and Earland, 1930

Miliammina cf. **valdensis** Bartenstein and Brand
Plate 4, figure 30

Miliammina valdensis BARTENSTEIN AND BRAND, 1951, Senckenb. Naturf. Ges., Abh., no. 485, p. 277, pl. 13, figs. 360–361.

A few specimens that seem to belong to this species were found in the Kimmeridgian of Maghara, northern Sinai. The specimens have a shorter neck than the form described from the Lower Cretaceous of northwestern Germany.

The figured specimen is from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai.

Family MILIOLIDAE

Genus AGATHAMMINA Neumayr, 1887

Agathammina antiqua Said and Barakat, **new species**
Plate 3, figure 13; plate 4, figures 28–29

Test small, tubular, undivided, winding about an elongate axis and forming an elongate rectangle; early whorls show slight overlapping, later becoming loosely coiled; wall calcareous, somewhat stained, imperforate; sutures distinct, slightly depressed; periphery rounded; aperture formed by the open end of the tubular chamber. Length 0.25 mm.; breadth 0.14 mm.

The holotype is from sample no. 489, Gebel Ingbashi, north of Bir Maghara. Paratypes are from sample no. 478, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species are recorded from the Callovian and Kimmeridgian of Gebel Maghara.

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina compressa Terquem and Berthelin
Plate 2, figure 5

Quinqueloculina compressa TERQUEM AND BERTHELIN, 1875, Soc. Géol. France, Mém., ser. 2, vol. 10, p. 85, pl. 7, fig. 11a–b.

Test small, quinqueloculine in plan, elongate, oval in outline, periphery rounded; wall calcareous, perforate; somewhat compressed; sutures distinct and depressed; aperture simple, at the end of the last-formed chamber.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species are recorded from the Bathonian of Gebel Maghara.

Genus MASSILINA Schlumberger, 1893

Massilina sp.
Plate 1, figure 6

Test free, small, narrow and elongate; early portion quinqueloculine, later chambers added alternately on opposite sides of the test; periphery rounded; four elongate chambers visible on each side of the test; sutures indistinct, slightly depressed; wall calcareous; aperture a rounded opening at the end of the final chamber. Length of figured specimen 0.25 mm.; greatest breadth 0.1 mm.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens of this small species are recorded from the Bajocian of Maghara.

Genus SPIROLOCULINA d'Orbigny, 1826

Spiroloculina sp.
Plate 2, figure 6

Test in the early chambers faintly quinqueloculine, later ones coiled in a single plane with chambers half a coil in length, low, somewhat translucent; aperture formed by the open end of the last chamber, without neck. Length 0.3 mm.; breadth 0.17 mm.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Bathonian of Gebel Maghara.

Genus SIGMOILINA Schlumberger, 1887

Sigmoilina sp.
Plate 3, figure 14

Test small, narrow, and elongate, with early chambers quinqueloculine, later ones added alternately on opposite sides of the test; periphery rounded; sutures distinct, slightly depressed; wall with an arenaceous layer; aperture a simple rounded opening at the end of the final chamber. Length 0.33 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens of this species were found in the Callovian of Gebel Maghara.

Family OPHTHALMIDIIDAE

Genus CORNUSPIRA Schultze, 1854

Cornuspira cf. **orbicula** (Terquem and Berthelin)
Plate 2, figure 7

Cornuspira orbicula (Terquem and Berthelin). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 17, pl. 1, fig. 16.

Test small, composed of a proloculum and a long, planispirally coiled second chamber, rounded; whorls increasing rapidly in width as formed; wall calcareous, imperforate; aperture formed by the open end of the last chamber, constricted, with a thickened lip.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

Genus SPIROPHTHALMIDIUM Cushman, 1927

Spirophthalmidium concentricum
(Terquem and Berthelin)
Plate 3, figure 15; plate 4, figure 31

Spiroloculina concentrica TERQUEM AND BERTHELIN, 1875, Soc. Géol. France, Mém., ser. 2, vol. 10, p. 80, pl. 7, figs. 1–4.

Test free, small, compressed, planispiral, proloculum followed by two chambers in each coil; periphery subacute; chambers narrow, elongate, gently arcuate; sutures distinct; wall calcareous, imperforate; aperture simple, at the open end of the chamber.

The figured specimens are from sample no. 489 (pl. 3, fig. 15), Gebel Ingbashi, north of Bir Maghara; and from sample no. 484 (pl. 4, fig. 31), along Wadi Imshash Rashed, Gebel Maghara, both in northern Sinai. A few specimens that seem to belong to this species are recorded from the Callovian and Kimmeridgian of northern Sinai.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina bartensteini Said and Barakat, **new species**
Plate 1, figure 7a–b

Test small, somewhat compressed, umbilicate on the ventral side; periphery subacute, slightly lobulate; chambers few, three or four in the final whorl, not very distinct, increasing rapidly in size as added; test composed of two to three volutions; sutures not distinct, depressed, nearly radial; wall arenaceous, composed of rather uniform sand grains, firmly cemented; aperture ventral, at the inner margin of the last-formed chamber. Diameter 0.25 mm.; thickness 0.11 mm.

This species may be the same as *Trochammina globigeriniformis* (Parker and Jones) as recorded by Bartenstein and Brand (1937) from the German Lias and Dogger. It differs from Recent specimens of *Trochammina globigeriniformis* in having a smaller and more depressed test, and in having a less lobulate periphery.

The holotype is from sample no. 22, Bathonian, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Trochammina depressula Said and Barakat, **new species**
Plate 4, figure 34a–c

Test trochoid, compressed; periphery lobulate, acute; chambers distinct, seven or eight in the last-formed coil, increasing rather uniformly in size as added, the general shape being rather constant; sutures distinct, depressed, straight; wall finely arenaceous; aperture a narrow opening on the ventral side, at the inner margin of the last-formed chamber. Diameter 0.33 mm.

This species is similar to *Trochammina diagonis* (Carsey) except for having a much smaller and more smoothly finished test and except for having the last whorl greatly developed, so as to form most of the test on the dorsal side.

The holotype is from sample no. 485, along Wadi Horma, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of Gebel Maghara.

Trochammina douvillei Said and Barakat, **new species**
Plate 4, figure 32a–c

Test small, trochoid, umbilical area open; periphery rounded; chambers triangular in outline, increasing greatly in size as added, so that the last-formed chamber makes up about one-half of the periphery on the dorsal side; as many as seven chambers in the last-formed whorl; sutures distinct, depressed, oblique; wall finely arenaceous, very smoothly finished; aperture ventral, at the inner margin of the last-formed chamber Diameter 0.27 mm.

This species differs from *Trochammina albertensis* Wickenden in having the characteristic triangular, rapidly increasing chambers, and in the wide ventral umbilicus.

The holotype is from sample no. 485, along Wadi Horma, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of northern Sinai.

Family LAGENIDAE

Genus ASTACOLUS Montfort, 1808

Astacolus crepidula (Fichtel and Moll)
Plate 1, figures 15–17; plate 3, figure 19; plate 5, figure 19

Cristellaria (Planularia) crepidula (Fichtel and Moll). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 169, pl. 2A, fig. 18b; pl. 3, fig. 48; pl. 4, fig. 76; pl. 5, fig. 74; pl. 9, fig. 45a–e; pl. 10, fig. 31; pl. 11A, fig. 11; pl. 11B, fig. 16a–b; pl. 12A, fig. 12a–d; pl. 12B, fig. 12a–d; pl. 13, fig. 31; pl. 14B, fig. 11; pl. 14C, fig. 12; pl. 15A, fig. 30; pl. 15C, fig. 15a–b.

Specimens that may belong to this species are similar to those described by Bartenstein and Brand from the Lias and Dogger of northwestern Germany. The Egyptian specimens have a rounded dorsal periphery and a truncate ventral periphery. The test is thick, and the sutures are gently curved dorsally.

The figured specimens are from sample no. 22 (pl. 1, figs. 15–17), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 19), Gebel Ingbashi, north of Bir Maghara; and from sample no. 485 (pl. 5, fig. 19), along Wadi Horma, Gebel Maghara; all in northern Sinai. Several specimens of this species were found in the Bajocian, Callovian and Kimmeridgian of the Maghara district.

Astacolus filosa (Terquem)
Plate 1, figures 13–14; plate 3, figure 17; plate 5, figure 32

Cristellaria (Planularia) filosa (Terquem). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 169, pl. 4, fig. 77; pl. 9, fig. 44; pl. 11A, fig. 10; pl. 11B, fig. 15a–b; pl. 12A, fig. 11; pl. 13, fig. 31; pl. 15A, fig. 29a–c; pl. 15C, fig. 14a–b.

Test auriculate in outline, compressed, coiled in the early portion, later part uncoiling, with the later chambers reaching back nearly to the proloculum; periphery acute and faintly keeled, particularly on the dorsal margin; chambers low and elongate, as many as eight in well developed specimens; sutures distinct, depressed, strongly curved dorsally; aperture radiate, at the dorsal angle.

This species differs from *Astacolus crepidula* (Fichtel and Moll) in having a more depressed test and in having more elongate later chambers.

The figured specimens are from sample no. 22 (pl. 1, figs. 13–14), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 17), Gebel Ingbashi, north of Bir Maghara; and from samples no. 477 (pl. 5, fig. 32) and no. 487, along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. This species is represented by a few small specimens in the Bajocian, and becomes abundant in both the Callovian and Kimmeridgian of Gebel Maghara.

Astacolus inaequistriata (Terquem)
Plate 1, figure 23

Cristellaria (Astacolus) inaequistriata (Terquem). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, pl. 2A, fig. 21a–c; pl. 2B, fig. 36a–b.

This is a distinct species that has a compressed test, an acute and keeled periphery, and as many as ten elongate and low chambers. The sutures are distinct and flush with the surface, and curve very gently dorsally. The test is ornamented with four fine longitudinal striae.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A very few specimens of this species are recorded from the Bajocian of northern Sinai.

Astacolus matutina (d'Orbigny)
Plate 1, figures 18–19

Cristellaria (Astacolus) matutina (d'Orbigny). – BARTENSTEIN AND BRAND, Senckenb. Naturf. Ges., Abh., no. 439, p. 172, pl. 2B, fig. 33; pl. 3, fig. 45; pl. 4, fig. 79; pl. 5, fig. 53; pl. 6, fig. 33.

Specimens referred to this species resemble *Astacolus prima* (d'Orbigny) in outline, but differ from that species in having a more depressed test, a keeled dorsal side, and more depressed and more distinct sutures. The transverse section of the test is oval, which differentiates this species from *Planularia protracta* (Bornemann).

The figured specimens are from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Egyptian Bajocian.

Astacolus minuta (Bornemann)
Plate 3, figure 16

Cristellaria (Lenticulina) minuta BORNEMANN, 1854, Lias von Göttingen, p. 42, pl. 4, fig. 37a–b.

Test small, depressed, consisting of seven chambers arranged in a coiled spire; later chambers with a tendency to uncoil; periphery subacute; sutures distinct, deeply depressed, diverging radially from the umbilicus of the early whorl; wall calcareous, finely perforate; surface smooth; aperture radiate, at the peripheral angle.

This species differs from *Astacolus crepidula* in having deeply depressed sutures and a subacute periphery.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens of this species are recorded from the Callovian of northern Sinai.

Astacolus pellucida Said and Barakat, **new species**
Plate 3, figure 18; plate 5, figure 36

Test free, of medium size, compressed, coiled in the early portion, later part uncoiling; chambers radial, becoming progressively more elongate as added; periphery acute; chambers low and elongate, as many as ten in well developed specimens; sutures distinct, slightly depressed; wall vitreous and semitransparent; aperture terminal and radiate, at the dorsal angle. Length of holotype 0.6 mm.

This species differs from *Astacolus filosa* (Terquem) in being larger and more compressed, and in having the sutures not radiating from the umbilicus of the early coiled part.

The holotype is from sample no. 489, Gebel Ingbashi, north of Bir Maghara; the figured paratype is from sample no. 482, along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. Several specimens of this species were found in the Callovian and Kimmeridgian of northern Sinai.

Astacolus prima (d'Orbigny)
Plate 1, fig. 20; plate 2, figure 11; plate 5, figure 40

Cristellaria (Astacolus) prima (d'Orbigny). – Bartenstein and Brand, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 172, pl. 1A, fig. 25; pl. 2A, fig. 17; pl. 3, fig. 44; pl. 4, fig. 81; pl. 5, fig. 54; pl. 6, fig. 32a–b; pl. 9, fig. 48a–b; pl. 10, fig. 37a–c; pl. 11A, fig. 12a–b; pl. 12A, fig. 15a–b; pl. 13, fig. 33a–b; pl. 15C, fig. 17a–b.

Test strongly coiled in the early portion, later uncoiling, with the later chambers reaching back to the early coiled part; periphery rounded; chambers slightly lower than long, as many as nine in well developed specimens; sutures indistinct, slightly depressed, curved dorsally very slightly if at all; aperture radiate, at the dorsal angle.

This species is distinguished by its well developed and more or less completely evolute earlier part. It differs from *Astacolus matutina* (d'Orbigny) in having a rounded periphery, less depressed sutures, and a thicker test.

The figured specimens are from sample no. 22 (pl. 1, fig. 20), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 429 (pl. 2, fig. 11), Gebel Somor, northwest of Bir Maghara; and from samples no. 477 (pl. 5, fig. 40) and no. 487, along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. Several specimens of this species are recorded from the Bajocian, Bathonian and Kimmeridgian of Gebel Maghara.

Astacolus stilla (Terquem)
Plate 1, figures 21–22

Cristellaria stilla Terquem, 1866, Sixième Mém. Foram. Lias, p. 517, pl. 22, fig. 7.

Specimens referred to this species are small, with a subacute, keeled periphery. The last one or two chambers become short and high. The sutures are very gently curved dorsally.

The figured specimens are from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. This species is represented by numerous specimens from the Egyptian Bajocian.

Astacolus sp.
Plate 3, figure 20

Test free, large, compressed; early portion coiled, planispirally evolute, later uncoiling; periphery subacute; chambers numerous, low and elongate, as many as eleven in well developed specimens, later uncoiled chambers reaching back to the coil; sutures distinct, slightly oblique, gently curved; wall calcareous, finely perforate; surface smooth; aperture radial, terminal, at the dorsal angle. Length 0.28 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Only two specimens of this species were found in the Callovian of northern Sinai.

Genus Lenticulina Lamarck, 1804

Lenticulina cf. **acutiangulata** (Terquem)
Plate 1, figure 8

Cristellaria (Lenticulina) acutiangulata (Terquem). – Bartenstein and Brand, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 175, pl. 5, fig. 52a–d.

Specimens that may belong to this species occur in the Egyptian Bajocian. The last chamber in this form is somewhat triangular in cross section, the two sides extending to cover the umbilical portion. The sutures are indistinct and slightly depressed.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Lenticulina magharaensis Said and Barakat, **new species**
Plate 4, figure 37a–b

Test lenticular, planispiral, involute, raised centrally in a small boss; chambers numerous, as many as twelve in the last whorl, increasing gradually in size as added; periphery acute, somewhat lobulate; sutures distinct, limbate, curved ventrally; wall calcareous, hyaline, translucent, surface smooth; aperture terminal, at the peripheral angle. Diameter 0.46 mm.

This species differs from *Lenticulina muensteri* (Roemer) in having limbate sutures, a translucent wall, and a slightly smaller boss.

The figured specimen is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Lenticulina muensteri (Roemer)
Plate 1, figure 10; plate 3, figure 25; plate 4, figure 35

Robulina muensteri ROEMER, 1839, Verstein. norddeutschen Oolithen-Gebirges, Nachtrag, p. 48, pl. 20, fig. 29.

This is a common species in the Bajocian, Callovian and Kimmeridgian material, which shows but little variation. The most characteristic features of the tightly coiled spiral test are the distinctly raised boss, the high chambers, and the very slightly limbate sutures.

The figured specimens are from sample no. 22 (pl. 1, fig. 10), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 25), Gebel Ingbashi, north of Bir Maghara; and from samples no. 478 (pl. 4, fig. 35) and no. 485, along Wadi Imshash Rashed and Wadi Horma, Gebel Maghara; all in northern Sinai.

Lenticulina quenstedti (Gümbel)
Plate 3, figure 24; plate 5, figure 34

Cristellaria quenstedti GÜMBEL, 1862, Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 18, p. 226, pl. 4, fig. 2. – MACFADYEN, 1935, Jurassic Foram., p. 14, text-fig. 13a–b.

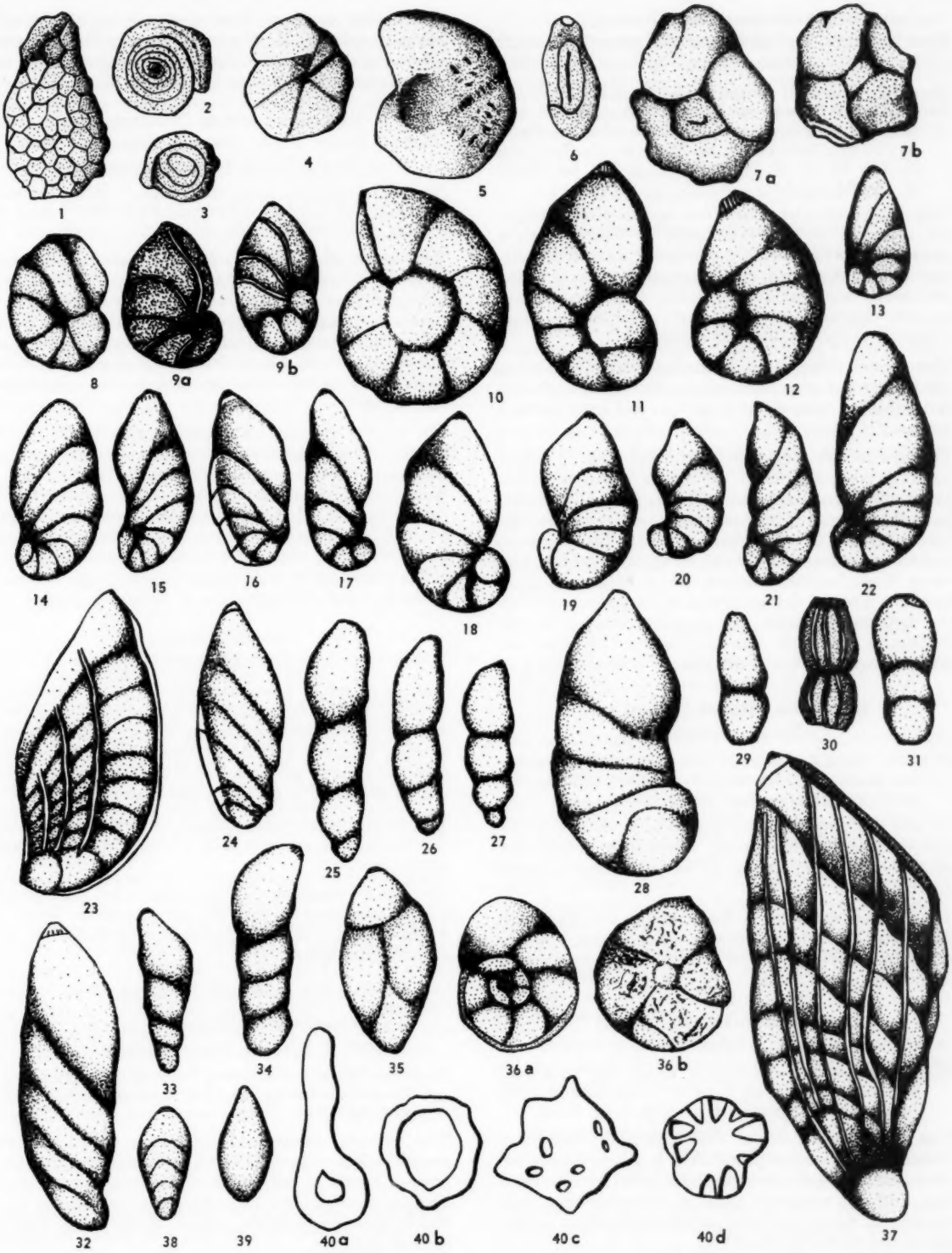
Test free, of medium size, consisting of about seven chambers arranged in a tightly coiled spire, compressed biconvex in cross section; sutures limbate, forming well marked ribs radiating from a central point, often forming a pseudoboss; wall calcareous, finely perforate; periphery subacute; aperture circular, at the outer margin of the spire.

The figured specimens are from sample No. 489 (pl. 3, fig. 24), Gebel Ingbashi, north of Bir Maghara; and from sample no. 477 (pl. 5, fig. 34), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. Several specimens of this species are recorded from the Callovian and Kimmeridgian of northern Sinai.

PLATE 1

Unless otherwise indicated, all specimens are from sample no. 22, Bajocian, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. All figures × 80.

1 *Proteonina difflugiformis* (H. B. Brady).
2 *Involutina magharaensis* Said and Barakat, n. sp.; holotype.
3 *Involutina aspera* (Terquem).
4 *Ammobaculites* cf. *cobbani* Loeblich and Tappan.
5 *Lituola* sp.; etched specimen.
6 *Massilina* sp.
7 *Trochammina bartensteini* Said and Barakat, n. sp.; holotype: a–b, dorsal and ventral views.
8 *Lenticulina* cf. *acutiangulata* (Terquem).
9 *Lenticulina varians* (Bornemann); a–b, different views of the same specimen.
10 *Lenticulina muensteri* (Roemer).
11 *Lenticulina subalata* (Reuss).
12 *Lenticulina subalata* (Reuss) var.
13–14 *Astacolus filosa* (Terquem).
15–17 *Astacolus crepidula* (Fichtel and Moll).
18–19 *Astacolus matutina* (d'Orbigny).
20 *Astacolus prima* (d'Orbigny).
21–22 *Astacolus stilla* (Terquem).
23 *Astacolus inaequistriata* (Terquem).
24 *Vaginulina constricta* (Terquem and Berthelin).
25 *Marginulina* sp.
26 *Dentalina* cf. *crenata* Schwager.
27 *Rectoglandulina tenuis* (Bornemann).
28 *Hemicristellaria vetusta* (d'Orbigny).
29 *Nodosaria crispata* Terquem.
30 *Nodosaria metensis* Terquem.
31 *Lingulina* sp.
32 *Marginulina simplex* (Terquem).
33 *Dentalina turgida* Schwager.
34 *Marginulina* cf. *oolitica* (Terquem).
35 *Eoguttulina* cf. *polygona* (Terquem).
36 *Epistomina costifera* Terquem; a–b, dorsal and ventral views. Sample 495, Bajocian, opposite Bir Maghara, northern Sinai.
37 *Citharina clathrata* (Terquem).
38 *Frondicularia lignaria* Terquem.
39 *Lagena ovata* (Terquem).
40a–d Holothuroid remains.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Lenticulina subalata (Reuss)
Plate 1, figure 11; plate 2, figure 18; plate 3, figure 22; plate 4, figure 26

Cristellaria (Lenticulina) subalata (Reuss). – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 176, pl. 6, fig. 35a–c; pl. 9, fig. 54a–c; pl. 10, fig. 41a–b; pl. 11A, fig. 15a–b; pl. 11B, fig. 22a–b; pl. 12A, fig. 18a–c; pl. 12B, fig. 16; pl. 13, fig. 38a–c; pl. 14B, fig. 16a–b; pl. 15A, fig. 35a–b.

Test small, lenticular, planispiral and involute; periphery subacute, with a faint keel; as many as eight chambers in well developed specimens; sutures distinct, very slightly thickened, curving gently backward at the periphery; wall calcareous, finely perforate, surface smooth; aperture at the dorsal angle of the final chamber, radiate, somewhat elongate.

This species differs from *Lenticulina münsteri* in having the sutures radiating from a non-elevated central disc, and in having more distinct, thinner, and less thickened sutures.

The figured specimens are from sample no. 22 (pl. 1, fig. 11), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 429 (pl. 2, fig. 18), Gebel Somor, northwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 22), Gebel Ingbashi, north of Bir Maghara; and from samples no. 477 (pl. 4, fig. 26) and no. 478, along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. A few specimens of this species occur in the Egyptian Bajocian. It becomes common in the Bathonian and more abundant in the Callovian and Kimmeridgian of Gebel Maghara.

Lenticulina subalata (Reuss) **var.**
Plate 1, figure 12

Cristellaria (Lenticulina) subalata (Reuss) form A. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 177, pl. 9, fig. 55a–f; pl. 10, fig. 42a–b.

Variety differing from the typical form in having the sutures radiating from a point, where they often form a pseudoboss, and in having the last chambers elongate and flaring.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens of this variety were found in the Bajocian of Sinai.

Lenticulina tricarinella (Reuss)
Plate 3, figure 23a–b

Cristellaria tricarinella REUSS, 1863, K. Akad. Wiss. Wien, Sitzber., vol. 46, p. 68, pl. 7, fig. 9. – MACFADYEN, 1935, Jurassic Foram. Somaliland, p. 15, pl. 1, fig. 18a–b.

Test composed of about four chambers; periphery truncate; the globular proloculum is followed by three chambers arranged in a close-coiled spire; sutures raised and limbate, radiating from a central point; wall calcareous, finely perforate; aperture terminal, at the apical end of the last chamber.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. Several specimens that seem to belong to this species are recorded from the Callovian of northern Sinai.

Lenticulina varians (Bornemann)
Plate 1, figure 9a–b; plate 2, figure 10; plate 3, figure 33a–b; plate 5, figure 33

Cristellaria (Lenticulina) varians (Bornemann). – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, p. 8, pl. 2, figs. 3–6.

Test small, involute; periphery truncate; chambers about six in number, arranged in a tightly coiled spire, later chambers as high as broad; sutures slightly raised, radiating from a central point; wall calcareous, finely perforate; aperture a slightly elongate radial opening at the dorsal side. In this species the last chamber tends to open up ventrally, trending toward a *Saracenaria*-like type of test.

The figured specimens are from sample no. 22 (pl. 1, fig. 9), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 429 (pl. 2, fig. 10), Gebel Somor, northwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 33a–b), Gebel Ingbashi; and from sample no. 482 (pl. 5, fig. 33), along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. Several specimens of this species are recorded from the Bajocian, Bathonian, Callovian, and Kimmeridgian of Gebel Maghara.

Lenticulina sp.
Plate 2, figure 8

Test free, small, lenticular, close-coiled, completely involute; periphery acute, with a faint keel; chambers numerous, increasing in size as added; sutures faintly distinct, originating from a central raised boss; wall calcareous, finely perforate; aperture radial and terminal, at the dorsal angle of the last chamber.

This species is probably related to *Lenticulina muensteri* (Roemer), from which it differs in having a less raised central boss.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A single specimen of this species is recorded from the Bathonian of Sinai.

Genus PLANULARIA Defrance, 1824

Planularia cordiformis Terquem
Plate 2, figure 9; plate 5, figure 1a–b

Cristellaria (Planularia) cordiformis Terquem. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 95, pl. 9, figs. 18–21.

Test arcuate, compressed; periphery truncate, with parallel edges; chambers about six in number, the later ones as broad as the length of the test; sutures very oblique, distinct, limbate; wall calcareous, finely perforate; aperture terminal, radiate, at the dorsal end of the last chamber.

The figured specimens are from sample no. 429, Gebel Somor, northwest of Bir Maghara; and from sample no. 485, along Wadi Horma, Gebel Maghara; both in northern Sinai. A few specimens of this species are recorded from the Bathonian and Kimmeridgian of Gebel Maghara.

Genus MARGINULINA d'Orbigny, 1826

Marginulina cf. **oolithica** (Terquem)
Plate 1, figure 34; plate 5, figure 26

Marginulina oolithica (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 74, pl. 7, fig. 17a–b.

A few specimens that seem to belong to this species were found in the Bajocian and Kimmeridgian of Maghara. The test is elongate, rounded in cross section, with few chambers, very slightly oblique sutures, a distinctly inflated and high last chamber, and a well developed radiate aperture.

The figured specimens are from sample no. 22 (pl. 1, fig. 34), Wadi Maghara, 700 meters southwest of Bir Maghara; and from sample no. 478 (pl. 5, fig. 26), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai.

Marginulina simplex (Terquem)
Plate 1, figure 32; plate 2, figure 17; plate 3, figure 26; plate 5, figure 3

Vaginulina simplex TERQUEM, 1864, Acad. Imp. Metz, Mém., vol. 44, p. 394, pl. 8, fig. 1a–b.

Test elongate, of medium size; chambers uniserially arranged, as many as six, inflated centrally, very slightly planispiral at the initial end, increasing gradually in breadth and height as added; last chamber inflated and rounded in cross section; sutures distinct, depressed, strongly oblique but not curved; aperture radiate, at the dorsal angle of the last chamber; wall calcareous, hyaline, smooth.

This species grades into *Vaginulina constricta* (Terquem and Berthelin) by compression of the test.

The figured specimens are from sample no. 22 (pl. 1, fig. 32), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 429 (pl. 2, fig. 17), Gebel Somor, northwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 26), Gebel Ingbashi, north of Bir Maghara; and from samples no. 478 (pl. 5, fig. 3) and no. 482, along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. A few specimens that seem to belong to this species were found in the Bajocian, Bathonian, Callovian, and Kimmeridgian of Gebel Maghara.

Marginulina sp.
Plate 1, figure 25

Test elongate; chambers few, as many as four, increasing rapidly in height and gradually in breadth; wall calcareous, hyaline; aperture radiate, situated dorsally, at the end of the last chamber; sutures distinct, strongly depressed so as to form constrictions between successive chambers. Length of figured specimen 0.45 mm. This species is characterized by its depressed sutures.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Genus HEMICRISTELLARIA Stache, 1864

Hemicristellaria vetusta (d'Orbigny)
Plate 1, figure 28; plate 5, figure 29

Cristellaria vetusta D'ORBIGNY, 1850, Prodrome, vol. 1, p. 242, no. 267.

Test arcuate in outline, coiled in early portion, later uncoiling, with the later chambers not reaching back to the early coiled part, depressed; periphery subacute dorsally, somewhat truncate ventrally; chambers numerous, as many as eight, gradually increasing in breadth and height as added; wall smooth, calcareous, hyaline; sutures depressed, indistinct; aperture radiate, at the dorsal side of the last chamber.

The figured specimens are from sample no. 22 (pl. 1, fig. 28), along Wadi Maghara, 700 meters southwest of Bir Maghara; and from sample no. 482 (pl. 5, fig. 29), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai.

Genus VAGINULINOPSIS Silvestri, 1904

Vaginulinopsis bartensteini Said and Barakat, **new species**
Plate 3, figure 27

Test free, large, elongate; early portion close-coiled, not umbilicate, depressed; later portion rectilinear, oval in section; chambers increasing in length as added, inflated, as many as four; sutures depressed, more so ventrally, radial at first, later tending to be horizontal; wall calcareous, hyaline; surface smooth; last chamber drawn out into a short neck, upon which the terminal, radiate aperture is located. Length 0.75 mm.; breadth of early coiled part 0.14 mm.; breadth of lower uniserial part 0.14 mm.

This species differs from *Vaginulinopsis eritheles* Loeblich and Tappan in the absence of a keel in the early cristellarian part, and in having a smaller earlier portion and a more developed uniserial portion.

The holotype is from sample no. 489, Gebel Ingbashi, northern Sinai. Several specimens of this species were found in the Callovian of Sinai.

Vaginulinopsis misrensis Said and Barakat, **new species**
Plate 5, figures 7a–c, 21a–b

Test free, elongate, compressed; early portion close-coiled, later portion rectilinear; chambers numerous, low and broad, five in the coil, followed by five or six

uncoiled chambers; sutures distinct, depressed, oblique; wall calcareous; surface smooth; aperture terminal and radiate.

This species differs from *Vaginulinopsis epicharis* Loeblich and Tappan, recorded from the Oxfordian of South Dakota, in having the chambers of the uniserial part distinctly triangular in section, and in being keeled and angular on the dorsal side and rounded on the ventral side. It also differs in having sutures that do not reach to the coil.

The holotype and paratype are from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A very few specimens of this species are recorded from the Kimmeridgian of Maghara.

Genus DENTALINA d'Orbigny, 1826

Dentalina arbuscula Terquem
Plate 2, figure 13

Dentalina arbuscula TERQUEM, 1866, Sixième Mém. Foram. Lias, p. 487, pl. 19, fig. 30.

Test smooth, elongate, slender; chambers numerous, as many as seven in number, added irregularly with regard to size, arranged in a linear series; last chamber drawn out into a point at the aperture, which is central, terminal and radiate; sutures very slightly oblique; indistinct, depressed; wall smooth, porcellanous.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Bathonian of Maghara.

Dentalina cf. **crenata** Schwager
Plate 1, figure 26

Dentalina crenata SCHWAGER, 1865, Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 21, p. 109, pl. 3, figs. 19, 25.

A few poorly preserved specimens that seem to belong to this species were found in the Maghara Bajocian. Our specimens have a distinctly high and slightly inflated last chamber, few chambers, and a well developed radiate aperture.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Dentalina pseudocommunis Franke
Plate 3, figure 29; plate 5, figure 5

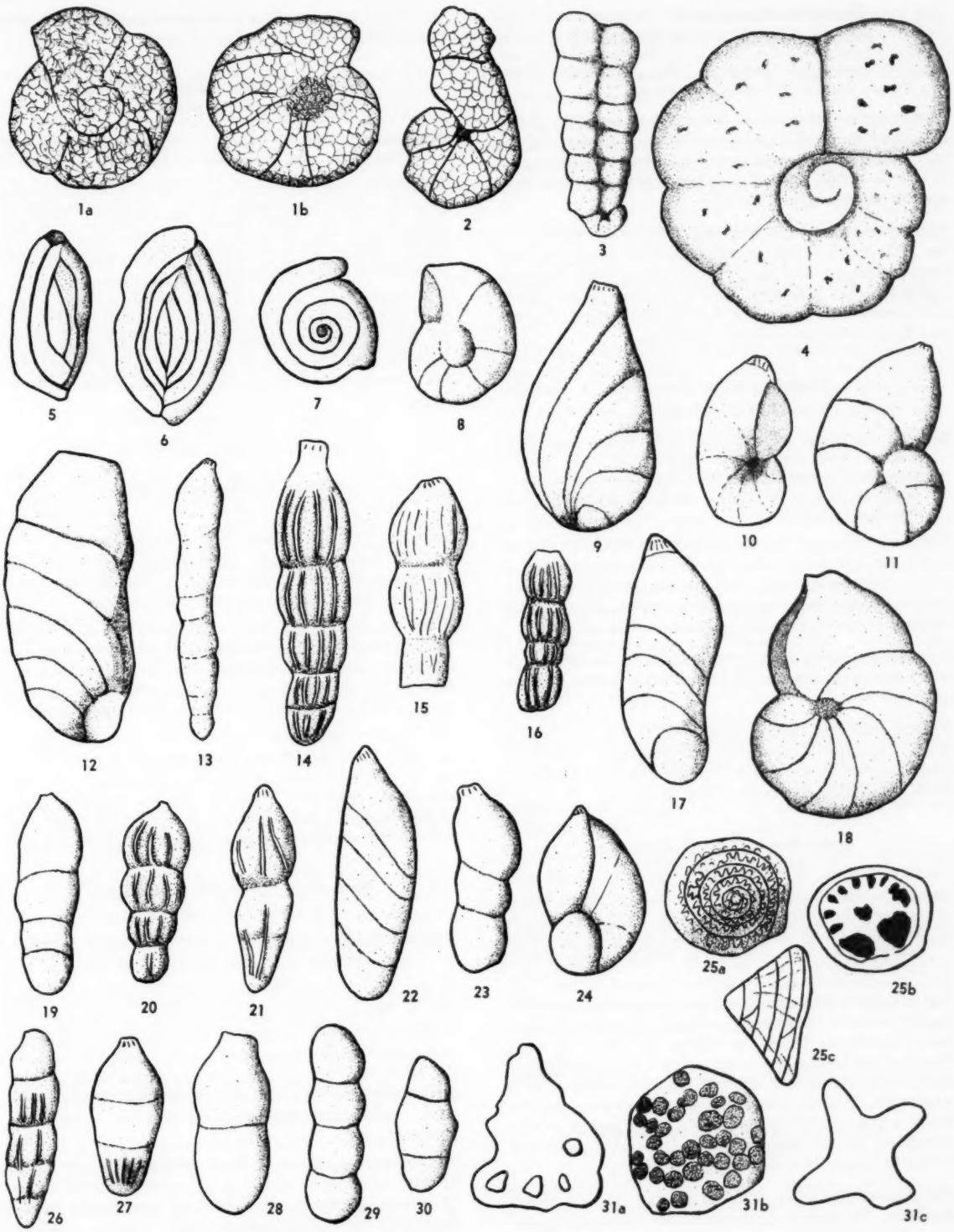
Dentalina pseudocommunis Franke. – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, p. 19, pl. 3, figs. 6–7.

Several specimens that seem to belong to this species are recorded from the Callovian and Kimmeridgian of northern Sinai. The figured specimens are from sample no. 489 (pl. 3, fig. 29), Gebel Ingbashi, north of Bir Maghara; and from sample no. 477 (pl. 5, fig. 5), along Wadi Imshash Rashed and Gebel Meleha, Maghara district; both in northern Sinai.

PLATE 2

All specimens are from sample no. 429, Bathonian, Gebel Somor, northwest of Bir Maghara, northern Sinai. All figures × 130.

1, 4 *Haplophragmoides barthouxi* Said and Barakat, n. sp.; 1a–b, dorsal and ventral views of paratype; 4, holotype.
2 *Ammobaculites fontinensis* (Terquem).
3 *Spiroplectammina biformis* (Parker and Jones).
5 *Quinqueloculina compressa* Terquem and Berthelin.
6 *Spiroloculina* sp.
7 *Cornuspira* cf. *orbicula* (Terquem and Berthelin).
8 *Lenticulina* sp.
9 *Planularia cordiformis* Terquem.
10 *Lenticulina varians* (Bornemann).
11 *Astacolus prima* (d'Orbigny).
12 *Vaginulina constricta* (Terquem and Berthelin).
13 *Dentalina arbuscula* Terquem.
14 *Nodosaria mitis* (Terquem and Berthelin).
15 *Nodosaria* cf. *crispata* Terquem.
16 *Nodosaria dolioligera* (Schwager).
17 *Marginulina simplex* (Terquem).
18 *Lenticulina subalata* (Reuss).
19 *Lingulina cernua* (Berthelin).
20 *Lingulina pupa* (Terquem).
21 *Nodosaria fontinensis* Terquem.
22 *Vaginulina legumen* (Linné).
23 *Dentalina sinemuriensis* Terquem.
24 *Saracenaria* cf. *triangularis* (d'Orbigny).
25 *Patellina douvillei* Said and Barakat, n. sp.; a–c, dorsal, ventral, and side views of holotype.
26 *Nodosaria opalini* Bartenstein and Brand.
27 *Rectoglandulina abbreviata* (Bornemann).
28 *Ellipsoglandulina* sp.
29 *Nodosaria simplex* (Terquem).
30 *Rectoglandulina humilis* (Roemer).
31 Holothuroid remains.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Dentalina sinemuriensis Terquem
Plate 2, figure 23; plate 5, figure 8

Dentalina sinemuriensis TERQUEM, 1866, Cinquième Mém. Foram. Lias, p. 405, pl. 15, fig. 6a–d.

Test smooth, composed of three chambers arranged in a slightly arcuate linear series; sutures highly oblique and well marked; chambers highly inflated, increasing in size as added, with their edges nearly parallel-sided; aperture submarginal, radiate.

The figured specimens are from sample no. 429 (pl. 2, fig. 23), Gebel Somor, northwest of Bir Maghara; and from sample no. 477 (pl. 5, fig. 8), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. A few specimens of this species are recorded from the Bathonian and Kimmeridgian of Gebel Maghara.

Dentalina torta Terquem
Plate 5, figure 4

Dentalina torta Terquem. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 27, pl. 2, fig. 9a–b. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 137, pl. 3, fig. 9; pl. 4, fig. 24; pl. 5, fig. 14; pl. 10, fig. 11.

Test free, elongate, slender, slightly arcuate; chambers numerous, gradually and rapidly increasing in size as added; sutures distinct, oblique, depressed; wall calcareous, finely perforate; periphery subacute; aperture radiate, on the dorsal side of the last chamber.

This species differs from *Dentalina vetustissima* d'Orbigny in being more slender and in having more oblique sutures.

The figured specimen is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of Gebel Maghara.

Dentalina turgida Schwager
Plate 1, figure 33

Dentalina turgida SCHWAGER, 1865, Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 21, p. 100, pl. 2, fig. 19; pl. 3, figs. 6, 11, 20. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 138, pl. 8, fig. 10a–b; pl. 9, fig. 13.

Test elongate, arcuate; chambers uniserially arranged, slightly inflated, increasing gradually in diameter and more rapidly in length as added, so that the final chamber is as high as it is broad and is distinctly inflated; sutures distinct, slightly depressed, slightly oblique; wall calcareous, hyaline, smooth; aperture radiate, at the dorsal angle of the last chamber. This species is distinguished by the form of its final chamber, which is distinctly larger than the earlier chambers.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai, Egypt. A few specimens of this species were found in the Bajocian of Gebel Maghara.

Dentalina vetustissima d'Orbigny
Plate 3, figure 28; plate 5, figure 6

Dentalina vetustissima d'Orbigny. – TERQUEM, 1858, Acad. Imp. Metz, Mém., vol. 39, p. 600, pl. 2, fig. 8.

Test small, free, tapering, consisting of about six chambers arranged in a linear series, straight, increasing gradually in size as added; sutures slightly depressed, faintly oblique; wall calcareous, hyaline; surface smooth; aperture terminal and radiate.

The figured specimens are from sample no. 489 (pl. 3, fig. 28), Gebel Ingbashi; and from sample no. 477 (pl. 5, fig. 6), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. A few specimens of this species were found in the Callovian and Kimmeridgian of Gebel Maghara.

Genus NODOSARIA Lamarck, 1816

Nodosaria crispata Terquem
Plate 1, figure 29; plate 2, figure 15; plate 3, figure 31; plate 5, figure 23

Nodosaria crispata Terquem. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 145, pl. 3, fig. 13; pl. 4, fig. 33; pl. 5, fig. 22.

A few specimens that seem to belong to this species were found in the Bajocian, Bathonian, Callovian, and Kimmeridgian of Gebel Maghara. The test is smooth, the chambers are few, elongate and separated by constrictions, and the aperture is rather long and radiate.

The figured specimens are from sample no. 22 (pl. 1, fig. 29), Wadi Maghara; from sample no. 429 (pl. 2, fig. 15), Gebel Somor, northwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 31), Gebel Ingbashi, north of Bir Maghara; and from sample no. 487 (pl. 5, fig. 23), Gebel Melha, Maghara district; all in northern Sinai.

Nodosaria dolioligera (Schwager)
Plate 2, figure 16

Dentalina dolioligera Schwager. – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, p. 16, text-fig. 8.

Test small, consisting of about four chambers arranged in a rectilinear series; first megalospheric chamber followed by a much smaller second chamber; following chambers barrel-shaped and more constricted toward the adult end; initial chambers as broad as high and ornamented by very fine striations running longitudinally; wall calcareous; aperture circular, central and terminal.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Only two specimens of this species were found in the Bathonian of Gebel Maghara.

Nodosaria fontinensis Terquem
Plate 2, figure 21

Nodosaria fontinensis Terquem. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 50, pl. 5, fig. 1.

Test very small, consisting of relatively few (about four) chambers, arranged in a rectilinear series; chambers spherical, increasing very slowly and regularly in diameter as added; last chamber in the form of an elongate ellipsoid drawn to a point at the aperture; sutures depressed, increasing in depth toward the adult end; wall calcareous, ornamented by three fine longitudinal costae that are distinct toward the younger end; aperture central, rounded, terminal and radiate.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species are recorded from the Bathonian of Gebel Maghara.

Nodosaria metensis Terquem
Plate 1, figure 30; plate 5, figure 20

Nodosaria metensis Terquem. – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 74, pl. 4, fig. 15a–c.

A few fragmentary specimens that seem to belong to this species were found in the Bajocian and Kimmeridgian at Maghara. The test is ornamented by a few faintly developed, thick costae, and the chambers are separated by constrictions.

The figured specimens are from sample no. 22 (pl. 1, fig. 30), Wadi Maghara, 700 meters southwest of Bir Maghara; and from sample no. 487 (pl. 5, fig. 20), Gebel Melha, Maghara district; both in northern Sinai.

Nodosaria nitidana Brand
Plate 5, figure 2

Nodosaria nitidana Brand. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 143, pl. 2B, fig. 22; pl. 4, fig. 32; pl. 5, fig. 27.

Test elongate, rectilinear; chambers as many as four, increasing gradually in diameter as added, slightly longer than broad; sutures distinct, straight, constricted; periphery rounded; wall calcareous, finely perforate; surface smooth; aperture radiate, terminal.

The figured specimen is from sample no. 487, Gebel Melha, Maghara district, northern Sinai. Several specimens of this species are recorded from the Kimmeridgian of Maghara.

Nodosaria mitis (Terquem and Berthelin)
Plate 2, figure 14

Nodosaria mitis (Terquem and Berthelin). – FRANKE, 1937, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 45, pl. 4, fig. 11a–b.

Test robust, consisting of five chambers arranged in a rectilinear series; chambers increasing gradually in width and length as added, so that the whole test becomes a narrow-angled cone; wall calcareous, ornamented by longitudinal ribs of variable number, which are well marked and raised slightly above the surface; aperture at the end of a neck.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens that seem to belong to this species were found in the Bathonian of Gebel Maghara.

Nodosaria opalini Bartenstein and Brand
Plate 2, figure 26

Nodosaria opalini BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 147, pl. 8, fig. 13a–b; pl. 10, fig. 18a–b.

Test small, elongate, slender, tapering toward the early stage, with parallel sides ornamented by very fine longitudinal striae; chambers increasing slowly in size; sutures faintly distinguishable, straight, slightly depressed; wall calcareous, finely perforate; aperture radiate, at the end of the last chamber.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Bathonian of Maghara.

Nodosaria simplex (Terquem)
Plate 2, figure 29; plate 5, figure 9

Nodosaria simplex (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 44, pl. 4, fig. 6. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 144, pl. 13, fig. 8.

Test small, consisting of a few chambers (about four) arranged in a rectilinear series; chambers spherical, increasing very slowly and regularly in diameter as added, so that the test has the appearance of being nearly parallel-sided; sutures distinct; wall calcareous, perforate; aperture terminal, radiate.

This form is distinguished from *Nodosaria dolioligera* (Schwager) by being much more regular in its growth as well as by having a smooth test.

The figured specimens are from sample no. 429 (pl. 2, fig. 29), Gebel Somor, northwest of Bir Maghara; and from sample no. 487 (pl. 5, fig. 9), Gebel Melha, Maghara district; both in northern Sinai. Several specimens of this species were found in the Bathonian and Kimmeridgian of Gebel Maghara.

Genus RECTOGLANDULINA Loeblich and Tappan, 1955

Rectoglandulina abbreviata (Bornemann)
Plate 2, figure 27

Glandulina abbreviata (Bornemann). – FRANKE, 1936, Preuss, Geol. Landesanst., Abh., new ser., no. 169, p. 59, pl. 5. fig. 24.

Test small, smooth, fusiform; chambers few (about four), increasing gradually in size as added; last-formed chamber making up a large portion of the test; wall calcareous, ornamented by numerous fine longitudinal striations, particularly obvious in the earlier part of the test; aperture terminal, radiate, situated on the drawn-out end of the last-formed chamber.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

Rectoglandulina hofkeri Said and Barakat, **new species**
Plate 5, figure 11a–b

Test elongate, rounded in section, tapering at the initial end; chambers wider than long, increasing gradually in size as added, enveloping, nearly parallel-sided in the adult part; sutures distinct, very slightly depressed; wall calcareous; surface smooth; aperture terminal and slit-like. Length 0.46 mm.; diameter 0.14 mm.

This species differs from *Rectoglandulina vulgata* (Bornemann) in having the chambers less inflated and the sutures very slightly depressed.

The holotype is from sample no. 487, Gebel Meleha, Maghara district, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Rectoglandulina humilis (Roemer)
Plate 2, figure 30

Pseudoglandulina humilis (Roemer). – Bartenstein and Brand, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 150, pl. 8, fig. 18.

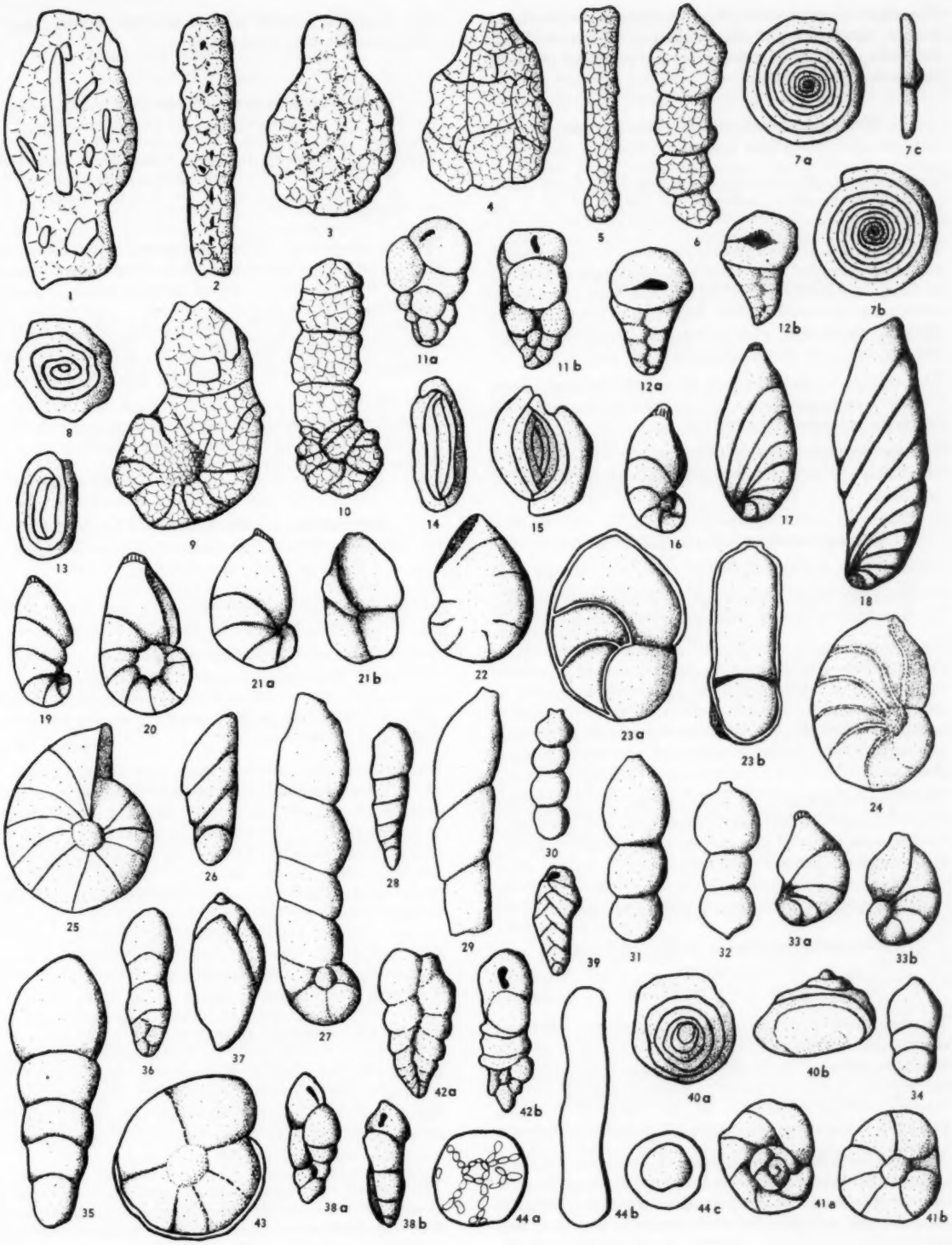
Test small, smooth; chambers few, about three in number, inflated, edges nearly parallel-sided; sutures slightly depressed; wall calcareous, finely perforate; aperture terminal, central, and circular.

This species differs from *Rectoglandulina abbreviata* (Bornemann) in being smaller in size and in appearing to taper toward both ends.

PLATE 3

All specimens are from sample no. 489, Callovian, Gebel Ingbashi, north of Bir Maghara, northern Sinai. All figure × 80 unless otherwise indicated.

1 *Rhabdammina* sp.
2 *Bathysiphon* sp. 1.
3 *Proteonina difflugiformis* (H. B. Brady).
4 *Proteonina* sp. 1.
5 *Hyperammina* sp. 1.
6 *Reophax* cf. *metensis* Franke.
7 *Ammodiscoides magharaensis* Said and Barakat, n. sp.; a–c, different views of holotype.
8 *Involutina gaultina* (Berthelin).
9 *Ammobaculites fontinensis* (Terquem).
10 *Bulbobaculites* sp.
11 *Verneuilinoides* sp.; a–b, different views.
12 *Marssonella* cf. *oxycona* (Reuss); a–b, different views.
13 *Agathammina antiqua* Said and Barakat, n. sp.; holotype.
14 *Sigmoilina* sp.
15 *Spirophthalmidium concentricum* (Terquem and Berthelin).
16 *Astacolus minuta* (Bornemann).
17 *Astacolus filosa* (Terquem).
18 *Astacolus pellucida* Said and Barakat, n. sp.; holotype.
19 *Astacolus crepidula* (Fichtel and Moll).
20 *Astacolus* sp.
21 *Saracenaria* cf. *triangularis* (d'Orbigny; a–b, different views.
22 *Lenticulina subalata* (Reuss).
23 *Lenticulina tricarinella* (Reuss); a–b, different views.
24 *Lenticulina quenstedti* (Gümbel).
25 *Lenticulina muensteri* (Roemer), ×40.
26 *Marginulina simplex* (Terquem).
27 *Vaginulinopsis bartensteini* Said and Barakat, n. sp.; holotype.
28 *Dentalina vetustissima* d'Orbigny.
29 *Dentalina pseudocommunis* Franke.
30, 32 *Orthomorphina terquemi* Said and Barakat, n. sp.; 30, holotype; 32, paratype.
31 *Nodosaria crispata* Terquem.
33 *Lenticulina varians* (Bornemann); a–b, different views.
34 *Lingulina minuta* Said and Barakat, n. sp.; holotype.
35 *Lingulina lanceolata* (Haeusler).
36 *Frondicularia* cf. *spissa* Terquem.
37 *Eoguttulina* cf. *polygona* (Terquem).
38 *Arenovirgulina aegyptiaca* Said and Barakat, n. sp.; a–b, different views of holotype.
39 *Bolivina* sp.
40 *Trocholina* cf. *transversarii* Paalzow; a–b, different views.
41 *Discorbis dreheri* Bartenstein; a–b, dorsal and ventral views.
42 *Paleogaudryina magharaensis*; a–b, different views of paratype.
43 *Epistomina parastelligera* (Hofker).
44 Holothuroid remains.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44c
38a
38b

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species are recorded from the Bathonian of Maghara.

Rectoglandulina tenuis (Bornemann)
Plate 1, figure 27

Glandulina tenuis (Bornemann). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 55, pl. 5, fig. 13a–b.

Test elongate, narrow, tapering, slightly compressed, periphery rounded; chambers few, overlapping, as many as four, increasing rapidly in height and breadth as added, last chamber slightly higher than broad; sutures distinct, depressed; wall calcareous, hyaline; surface smooth; aperture terminal, radiate.

This species is characterized by its few, inflated chambers and elongate form, and by having the chambers distinctly separate and overlapping.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Rectoglandulina vulgata (Bornemann)
Plate 5, figure 28a–b

Rectoglandulina vulgata (Bornemann). – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, p. 24, pl. 1, fig. 7.

Test free, elongate, rectilinear; chambers numerous, as many as five in mature specimens, increasing gradually in diameter as added, enveloping, increasing rapidly in length as added; sutures distinct, depressed, slightly arching anteriorly; wall calcareous, finely perforate; surface smooth; aperture terminal and radiate, on a short neck.

The figured specimen is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species are recorded from the Kimmeridgian beds of Maghara.

Genus SARACENARIA Defrance, 1824

Saracenaria aegyptiaca Said and Barakat, **new species**
Plate 5, figure 18a–b

Test free, early portion coiled, later uncoiling, with test subtriangular in section; chambers increasing gradually in size as added; sutures distinct, faintly depressed; wall calcareous, finely perforate; surface appears to be smooth; aperture radiate, at the peripheral angle. Length 0.48 mm.; diameter of rectilinear portion 0.3 mm.

This species differs from *Saracenaria cornucopiae* (Schwager) in the absence of keels on the angles of the rectilinear part and of a neck upon which the aperture is situated, and in having fewer chambers in the rectilinear part.

The holotype is from sample no. 487, Gebel Meleha, Maghara district, northern Sinai.

Saracenaria cornucopiae (Schwager)
Plate 5, figure 17a–b

Cristellaria (Saracenaria) cornucopiae Schwager. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439. p. 170, pl. 14B, fig. 12a–b; pl. 15A, fig. 31a–b; pl. 15c, fig. 16.

Test comparatively large, elongate, triangular in section; early portion close-coiled, later chambers uncoiled and rectilinear; coiled portion small, chambers increasing rapidly in size as added, a longitudinal keel present on each of the three angles; sutures distinct, slightly depressed; wall calcareous, perforate; aperture radiate, at the peripheral angle, situated on a short neck.

The figured specimen is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A few specimens of this species are recorded from the Kimmeridgian of northern Sinai.

Saracenaria cf. **triangularis** (d'Orbigny)
Plate 2, figure 24; plate 3, figure 21a–b; plate 5, figure 15a–b

Cristellaria triangularis D'ORBIGNY, 1840, Soc. Géol. France, Mém., ser. 1, vol. 4, p. 27, pl. 2, figs. 21–22.

Test with the earliest chambers close-coiled; subsequent ones swell rapidly and become triangular in cross section; wall smooth, calcareous, finely perforate; sutures indistinct; aperture radiate, situated at the peripheral angle of the triangular face.

The figured specimens are from sample no. 429 (pl. 2, fig. 24), Gebel Somor, northwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 21), Gebel Ingbashi, north of Bir Maghara; and from sample no. 477 (pl. 5, fig. 15), along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai. A few specimens of this species were found in the Bathonian, Callovian and Kimmeridgian of Gebel Maghara.

Saracenaria sp.
Plate 5, figure 16a–b

Test small, elongate, depressed, early portion close-coiled, later portion arcuate, rectilinear, acutely triangular in section; chambers increasing rapidly in height; sutures strongly curved, making the first coil convex upward, distinct, slightly depressed; periphery acute and keeled dorsally; wall calcareous, perforate; aperture terminal, radiate, at the dorsal angle.

The figured specimen is from sample no. 477, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of northern Sinai.

Genus LINGULINA d'Orbigny, 1826

Lingulina cernua (Berthelin)
Plate 2, figure 19

Lingulina cernua (Berthelin). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 61, pl. 6, fig. 8a–d. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 151, pl. 4, fig. 51; pl. 5, fig. 34; pl. 6, fig. 18; pl. 8, fig. 22.

Test minute, consisting of about four distinct chambers arranged in a rectilinear series, compressed, oval in cross section; chambers increasing gradually in size as added; sutures indistinct, slightly arched; aperture central, terminal, slit-like.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

Lingulina dentaliniformis Terquem
Plate 5, figure 30

Lingulina dentaliniformis TERQUEM, 1870, Acad. Imp. Metz, Mém., vol. 51, p. 339, pl. 15, figs. 1–3.

Test elongate, compressed, uniserial, rectilinear; proloculum globular, later chambers compressed, but the last two slightly inflated, increasing gradually in size as added; sutures distinct, depressed, arched gently upward over the center of the test; wall calcareous, smooth; periphery subacute; aperture terminal and elongate.

The figured specimen is from sample no. 487, Gebel Meleha, Maghara district, northern Sinai. A very few specimens of this species were found in the Kimmeridgian of Maghara.

Lingulina lanceolata (Haeusler)
Plate 3, figure 35; plate 5, figure 12

Lingulina lanceolata (Haeusler). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 62, pl. 6, fig. 10.

Test free, of medium size, uniserial, elongate, compressed; margins subacute; chambers increasing gradually in breadth and thickness as added; sutures distinct, slightly depressed, arched centrally; wall calcareous, finely perforate; surface smooth; aperture terminal, on a short neck and, in well preserved specimens, having a radial character.

The figured specimens are from sample no. 489, Gebel Ingbashi, north of Bir Maghara; and from sample no. 487, Gebel Melha, Maghara district, northern Sinai. This species in found in abundance in the Callovian and Kimmeridgian of Gebel Maghara.

Lingulina minuta Said and Barakat, **new species**
Plate 3, figure 34

Test free, small, uniserial, oval in cross-section; chambers as many as three, margins subacute, increasing gradually in breadth and length as added; proloculum rounded and large; sutures distinct, anteriorly arched, slightly depressed; wall calcareous, finely perforate; surface smooth; aperture simple, central and terminal, on a short neck. Length 0.23 mm.; breadth 0.01 mm.

This species differs from *Lingulina lanceolata* (Haeusler) in having a thicker, stouter and much smaller test. It differs from *Lingulina cernua* (Berthelin) in having fewer chambers, which become broader as added.

The holotype is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai.

Lingulina pupa (Terquem)
Plate 2, figure 20

Marginulina pupa TERQUEM, 1866, Cinquième Mém. Foram. Lias, p. 429, pl. 17, fig. 7a–f.

Test small, consisting of four chambers, slightly compressed in cross section; chambers few, about four in number, increasing gradually but rapidly in length and breadth; wall calcareous, porcellanous, ornamented with numerous fine longitudinal striations; aperture terminal, slit-shaped.

This species differs from *Lingulina cernua* (Berthelin) in having a more elongate and striated test.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Bathonian of Gebel Maghara.

Lingulina sp.
Plate 1, figure 31

Test elongate, periphery subacute; chambers inflated, as few as three, increasing gradually in height and breadth as added, last chamber highly inflated; sutures distinct, gently depressed, faintly arched; aperture radiate, terminal, on a short neck; wall calcareous, hyaline, smooth.

This species differs from *Lingulina dentaliniformis* Terquem in having the sutures slightly more arched, in having fewer chambers, a subacute periphery, and a necked aperture.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina constricta (Terquem and Berthelin)
Plate 1, figure 24; plate 2, figure 12; plate 5, figure 38

Marginulina constricta TERQUEM AND BERTHELIN, 1875, Soc. Géol. France, Mém., ser. 2, vol. 10, p. 58, pl. 5, fig. 3a–f.

Test elongate, narrow, compressed; periphery truncate ventrally, subacute dorsally; chambers numerous, as many as six, low and elongate, highest dorsally, increasing gradually in breadth as added; sutures dis-

tinct, oblique, not curved, depressed; wall calcareous, hyaline; surface smooth; aperture terminal, at the dorsal angle, distinctly radiate.

This species differs from *Vaginulina mecyna* Loeblich and Tappan in having fewer chambers, a more depressed test, and an aperture which is not protruding on a neck.

The figured specimens are from sample no. 22 (pl. 1, fig. 24), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 429 (pl. 2, fig. 12), Gebel Somor, northwest of Bir Maghara; and from sample no. 487 (pl. 5, fig. 38), Gebel Melha, Maghara district; all in northern Sinai. A few specimens of this species were found in the Bajocian, Bathonian and Kimmeridgian of Gebel Maghara.

Vaginulina legumen (Linné)
Plate 2, figure 22

Vaginulina legumen (Linné). – Bartenstein and Brand, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 162, pl. 15A, fig. 22; pl. 15C, fig. 10a–c.

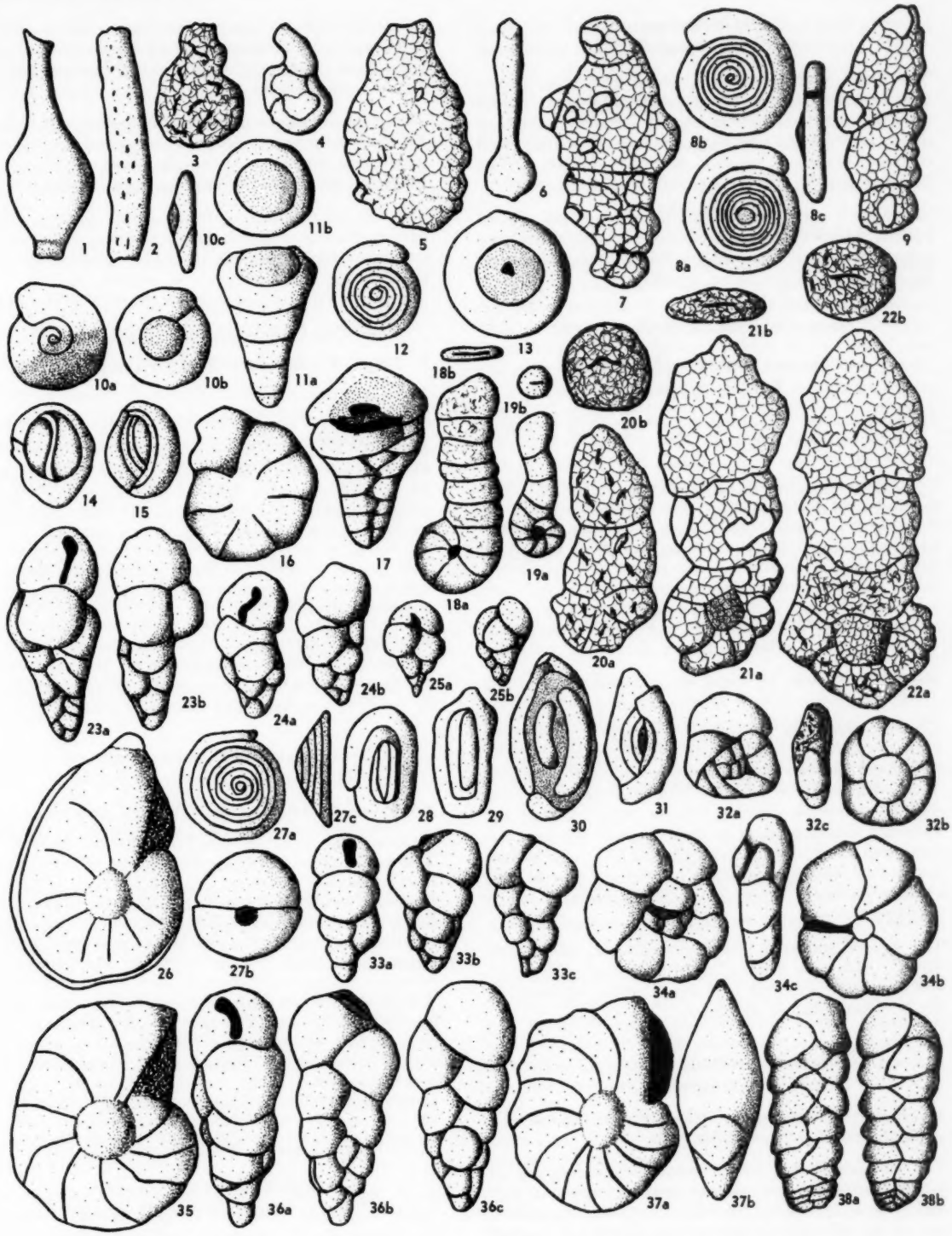
Test slightly compressed, triangular in outline; chambers few (about four), with a small and almost spherical proloculum; sutures depressed and highly oblique; wall calcareous, finely perforate; aperture radiate, subterminal, at the pointed end of the last chamber.

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

PLATE 4

All specimens from the Kimmeridgian of northern Sinai. All figures × 80 unless otherwise indicated.

1 *Rhabdammina aegyptiaca* Said and Barakat, n. sp.; holotype. Sample no. 477.
2 *Bathysiphon* sp. 2, × 40. Sample no. 485.
3 *Proteonina difflugiformis* (H. B. Brady). Sample no. 487.
4 *Lituotuba* sp. Sample no. 487.
5 *Proteonina* sp. 2. Sample no. 477.
6 *Hyperammina* sp. 2. Sample no. 485.
7 *Reophax barnardi* Said and Barakat, n. sp.; holotype. Sample no. 478.
8 *Ammodiscoides magharaensis* Said and Barakat, n. sp.; a–c, ventral, dorsal and side views of paratype. Sample no. 478.
9 *Reophax scorpiurus* Montfort. Sample no. 477.
10 *Conicospirillina planorbis* Said and Barakat, n. sp.; a–c, dorsal, ventral and side views of holotype. Sample no. 485.
11 *Nodosinella brandi* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 482.
12 *Involutina magharaensis* Said and Barakat, n. sp.; paratype. Sample no. 477.
13 *Annulina* cf. *metensis* Terquem. Sample no. 482.
14 *Glomospira compacta* Said and Barakat, n. sp.; holotype. Sample no. 478.
15 *Glomospira jurassica* Said and Barakat, n. sp.; holotype. Sample no. 478.
16 *Haplophragmoides* sp. Sample no. 478.
17 *Marssonella* cf. *oxycona* (Reuss). Sample no. 478.
18 *Ammomarginulina pellucida* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 485.
19 *Ammobaculites elegantissima* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 487.
20, 22 *Ammobaculites glaessneri* Said and Barakat, n. sp.; 20, paratype; 22, holotype: a–b, lateral and apertural views. Sample no. 487.
21 *Ammobaculites magharaensis* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 477.
23 *Verneuilinoides attenuata* Said and Barakat, n. sp.; a–b, apertural and lateral views of holotype. Sample no. 484.
24 *Verneuilinoides loeblichi* Said and Barakat, n. sp.; a–b, apertural and lateral views of holotype. Sample no. 484.
25 *Verneuilinoides minuta* Said and Barakat, n. sp.; a–b, apertural and lateral views of holotype. Sample no. 484.
26 *Lenticulina subalata* (Reuss). Sample no. 477.
27 *Conicospirillina* cf. *trochoides* (Berthelin); a–c, dorsal, ventral and side views. Sample no. 484.
28–29 *Agathammina antiqua* Said and Barakat; 28, ventral view; 29, dorsal view of another specimen. Sample no. 489.
30 *Miliammina* cf. *valdensis* Bartenstein and Brand. Sample no. 478.
31 *Spirophthalmidium* cf. *concentricum* (Terquem and Berthelin). Sample no. 484.
32 *Trochammina douvillei* Said and Barakat, n. sp.; a–c, dorsal, ventral and apertural views of holotype. Sample no. 485.
33, 36 *Paleogaudryina magharaensis* Said and Barakat, n. sp.; 33, paratype; 36, holotype; a–c, apertural and lateral views. Sample no. 478.
34 *Trochammina depressula* Said and Barakat, n. sp.; a–c, dorsal, ventral and apertural views of holotype. Sample no. 485.
35 *Lenticulina muensteri* Roemer. Sample no. 478.
37 *Lenticulina magharaensis* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 484.
38 *Dorothia terquemi* Said and Barakat, n. sp.; a–b, dorsal and ventral views of holotype. Sample no. 478.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Vaginulina sp.
Plate 5, figure 27

Test small, flattened, broad, coiled at the base, later tending to uncoil; sutures slightly depressed, faintly curving, radial; chambers slightly inflated, increasing slowly in height as added; periphery subrounded; wall calcareous, surface smooth; aperture radiate, at the dorsal angle.

The figured specimen is from sample no. 487, Gebel Melha, Maghara district, northern Sinai. Only two specimens of this species were found in samples from the Kimmeridgian of Gebel Maghara.

Genus CITHARINA d'Orbigny, 1839

Citharina clathrata (Terquem)
Plate 1, figure 37

Vaginulina clathrata (Terquem). – BARNARD, 1950, Geol. Soc. London, Quart. Jour., vol. 106, p. 29, pl. 1, figs. 8–10; text-fig. 17.

Typical specimens of this species occur in the Egyptian Bajocian. This species has been described amply by Barnard. The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai.

Citharina flabelloides (Terquem)
Plate 5, figure 25

Marginulina flabelloides TERQUEM, 1868, Soc. Hist. Nat. Moselle, Bull., vol. 2, p. 102, pl. 6, figs. 1–30.

Test free, flattened, subtriangular in outline, peripheral margin nearly straight; chambers increasing rapidly in breadth as added but increasing very little in height, as many as eight in well developed specimens; sutures slightly depressed, distinct, slightly curved toward the aperture, radial, tending to reach back to the proloculum; wall calcareous, ornamented by fine longitudinal costae that cross the chambers but not the sutures; ribs about equidistant; aperture terminal, radiate, at the peripheral angle.

The figured specimen is from sample no. 487, Gebel Melha, Maghara district, northern Sinai. Only two specimens of this species were found in the samples from the Kimmeridgian of Maghara.

Citharina inconstans (Terquem)
Plate 5, figure 24

Marginulina inconstans TERQUEM, 1868, Soc. Hist. Nat. Moselle, Bull., vol. 2, p. 66, pl. 2, figs. 1–12.

Test elongate, large, much compressed, triangular in outline; periphery truncate; chambers numerous, low and broad, increasing rapidly in breadth as added, increasing very little in height; sutures distinct, slightly depressed, radial, tending to reach back to the proloculum; wall calcareous, hyaline; surface smooth, ornamented by numerous narrow longitudinal ribs that cross both chambers and sutures obliquely; aperture terminal and radiate.

The chief difference between this species and *Citharina flabelloides* (Terquem) lies in the nature of the ornamentation and the shape of the chambers, which become longer on the dorsal side than on the ventral side.

The figured specimen is from sample no. 487, Gebel Melha, Maghara district, northern Sinai. A few broken specimens that seem to belong to this species were found in the Kimmeridgian of northern Sinai.

Genus FRONDICULARIA Defrance, 1824

Frondicularia lignaria Terquem
Plate 1, figure 38

Frondicularia lignaria TERQUEM, 1866, Sixième Mém. Foram. Lias, p. 480, pl. 19, fig. 14.

Test flattened, small, rhomboidal in outline, periphery acute; chambers few, five in number, very slightly arched; sutures distinct, depressed; wall calcareous, hyaline, smooth; aperture terminal and elongate.

This species is similar to *Frondicularia oolitica* Terquem but is narrower in outline and slightly thicker, and the chambers are fewer.

The figured specimen is from sample no. 22, Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens of this species were found in the Egyptian Bajocian.

Frondicularia cf. **spissa** Terquem
Plate 3, figure 36; plate 5, figure 14

Frondicularia spatulata (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 66, pl. 6, fig. 23.

Test small, greatly compressed, biserial in early stages, later uniserial; chambers slightly inflated, increasing gradually in size as added, with almost straight parallel sides; sutures chevron-shaped, strongly arched anteriorly; wall calcareous, finely perforate; aperture terminal, in the form of a slit.

The figured specimens are from sample no. 489 (pl. 3, fig. 36), Gebel Ingbashi, north of Bir Maghara; and from sample no. 482 (pl. 5, fig. 14), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. A few specimens of this species are recorded from the Callovian and Kimmeridgian of northern Sinai.

Genus LAGENA Walker and Boys, 1784

Lagena ovata (Terquem)
Plate 1, figure 39; plate 5, figure 31

Lagena ovata (Terquem). – FRANKE, 1936, Preuss. Geol. Landesanst., Abh., new ser., no. 169, p. 90, pl. 9, fig. 5.

A few specimens that belong to this species were found in the Bajocian and Kimmeridgian of Maghara. This species has a smooth, oval test. The aperture is not as distinctly radiate as in Terquem's type figure.

The figured specimens are from sample no. 22 (pl. 1, fig. 39), Wadi Maghara, 700 meters southwest of Bir Maghara; and from sample no. 487 (pl. 5, fig. 31), Gebel Melha, Maghara district; both in northern Sinai.

Family POLYMORPHINIDAE

Genus EOGUTTULINA Cushman and Ozawa, 1930

Eoguttulina cf. **polygona** (Terquem)
Plate 1, figure 35; plate 3, figure 37; plate 5, figure 39

Eoguttulina polygona (Terquem). – CUSHMAN AND OZAWA, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 17, pl. 1, fig. 1.

A few poorly preserved specimens that seem to belong to this species were found in the Bajocian, Callovian and Kimmeridgian of Maghara. Our specimens have poorly developed, depressed sutures, a radiate aperture, and a calcareous hyaline wall. This species is similar to *Eoguttulina liassica* (Strickland), but differs in having depressed sutures.

The figured specimens are from sample no. 22 (pl. 1, fig. 35), Wadi Maghara, 700 meters southwest of Bir Maghara; from sample no. 489 (pl. 3, fig. 37), Gebel Ingbashi, north of Bir Maghara; and from sample no. 477 (pl. 5, fig. 39), along Wadi Imshash Rashed, Gebel Maghara; all in northern Sinai.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion jurassicum Said and Barakat, **new species**
Plate 5, figure 37a–c

Test slightly longer than broad, depressed, nearly bilaterally symmetrical, partially evolute, umbilical portion depressed, revealing the earlier whorls; chambers distinct, as many as twelve in the last-formed whorl, of uniform shape, gradually increasing in size as added, somewhat inflated; sutures distinct, depressed, gently curved; wall smooth, polished, very finely perforate; aperture apparently a slit at the base of the last-formed chamber. Length 0.5 mm.; breadth 0.33 mm.

This species is slightly asymmetrical in apertural view; this fact, together with its evoluteness, may place it in *Nonionella* Cushman, but it does not have the elongate lobe at the umbilicus.

The holotype is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of Gebel Maghara. A similar record of this species in the Cenomanian of Sinai has been given by the authors (MS.) under the name "*Nonion* sp."

Family HETEROHELICIDAE

Genus ORTHOMORPHINA Stainforth, 1952

Orthomorphina terquemi Said and Barakat, **new species**
Plate 3, figures 30, 32; plate 5, figure 13a–b

Test free, small, elongate, rectilinear; chambers as many as four, as long as broad in the first two chambers, becoming broader than long in the last two chambers, globular; sutures distinct, deeply depressed, straight; wall calcareous, perforate; surface faintly hispid; last chamber provided with a neck bearing the simple, rounded terminal aperture. Length 0.35 mm.; diameter 0.05 mm. in the specimens shown in plate 3, figures 30 and 32.

This species is very similar to, if not identical with *Dentalina mauritii* Terquem. It is highly probable that Terquem's *Dentalina*, which remained so long a problematical form, belongs to the genus *Orthomorphina* Stainforth. The arrangement of the chambers and the characters of the nonradiate aperture seem to support this view. A few specimens that appear to belong to the megalospheric generation, in which the proloculum is large and the number of chambers is fewer, are also recorded.

The holotype and one paratype are from sample no. 489, Gebel Ingbashi, north of Bir Maghara (pl. 3, figs. 30, 32); the other paratype is from sample no. 487, Gebel Melha, Maghara district (pl. 5, fig. 13); both in northern Sinai. This species is abundant in the Callovian and Kimmeridgian of northern Sinai.

Family BULIMINIDAE

Genus BOLIVINA d'Orbigny, 1839

Bolivina bartensteini Said and Barakat, **new species**
Plate 5, figure 10a–b

Test small, compressed, tapering; chambers typically biserial, faintly inflated, increasing rather rapidly in size as added; sutures indistinct, faintly depressed, slightly oblique; wall calcareous, finely perforate, somewhat translucent; periphery subacute; aperture elongate, terminal, somewhat loop-shaped.

This species differs from *Bolivina rhumbleri* Franke in having less oblique sutures and more inflated and more numerous chambers.

The holotype is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Bolivina sp.
Plate 3, figure 39

Test free, small, elongate, compressed, tapering, slightly arcuate; chambers typically biserial; wall calcareous, finely perforate; surface smooth; aperture somewhat loop-shaped, at the base of the apertural face of the last chamber. Length 0.25 mm.; breadth of upper part 0.1 mm.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens were found in the Callovian of northern Sinai.

Family ELLIPSOIDINIDAE

Genus ELLIPSOGLANDULINA Silvestri, 1900

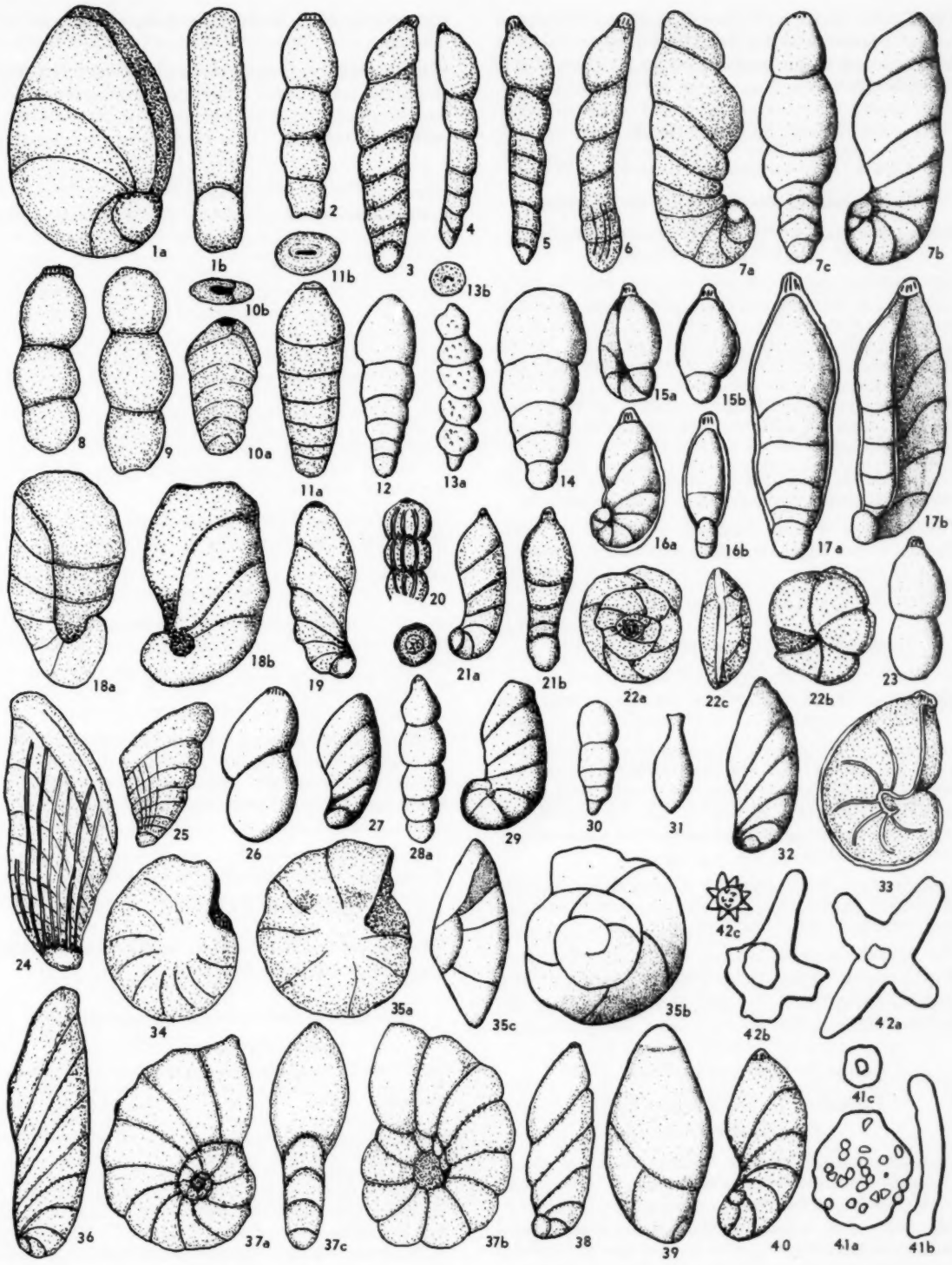
Ellipsoglandulina sp.
Plate 2, figure 28

Test small, somewhat parallel-sided; chambers few, two in number, flask-shaped, slightly enveloping, somewhat inflated; sutures distinct, slightly depressed; periphery rounded; wall calcareous, finely perforate; aperture terminal, slightly elongate, drawn out into a neck. Length 0.25 mm.; breadth 0.13 mm.

PLATE 5

All specimens from the Kimmeridgian of northern Sinai. All figures × 80 unless otherwise indicated.

1 *Planularia cordiformis* (Terquem); a–b, lateral and apertural views. Sample no. 485.
2 *Nodosaria nitidana* (Brand). Sample no. 487.
3 *Marginulina simplex* (Terquem). Sample no. 478.
4 *Dentalina torta* Terquem. Sample no. 477.
5 *Dentalina pseudocommunis* Franke. Sample no. 477.
6 *Dentalina vetustissima* d'Orbigny. Sample no. 477.
7, 21 *Vaginulinopsis misrensis* Said and Barakat, n. sp.; 7, holotype; 21, paratype; a–c, dorsal, ventral and apertural views. Sample no. 477.
8 *Dentalina sinemuriensis* Terquem. Sample no. 477.
9 *Nodosaria simplex* (Terquem). Sample no. 487.
10 *Bolivina bartensteini* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 484.
11 *Rectoglandulina hofkeri* Said and Barakat, n. sp.; a–b, lateral and apertural views of holotype. Sample no. 487.
12 *Lingulina lanceolata* (Haeusler). Sample no. 487.
13 *Orthomorphina terquemi* Said and Barakat, n. sp.; a–b, lateral and apertural views of paratype. Sample no. 487.
14 *Frondicularia* cf. *spissa* Terquem. Sample no. 482.
15 *Saracenaria* cf. *triangularis* (d'Orbigny); a–b, lateral and apertural views. Sample no. 477.
16 *Saracenaria* sp.; a–b, lateral and apertural views. Sample no. 477.
17 *Saracenaria cornucopiae* (Schwager); a–b, apertural and lateral views. Sample no. 477.
18 *Saracenaria aegyptiaca* Said and Barakat, n. sp.; a–b, apertural and lateral views of holotype. Sample no. 487.
19 *Astacolus crepidula* (Fichtel and Moll). Sample no. 485.
20 *Nodosaria metensis* (Terquem). Sample no. 487.
22 *Epistomina depressa* Said and Barakat n. sp.; a–c, dorsal, ventral and lateral views of holotype. Sample no. 477.
23 *Nodosaria crispata* (Terquem). Sample no. 487.
24 *Citharina inconstans* (Terquem), × 40. Sample no. 487.
25 *Citharina flabelloides* (Terquem), × 40. Sample no. 487.
26 *Marginulina* cf. *oolithica* (Terquem). Sample no. 478.
27 *Vaginulina* sp. Sample no. 482.
28 *Rectoglandulina vulgata* (Bornemann); a–b, lateral and apertural views. Sample no. 477.
29 *Hemicristellaria vetusta* (d'Orbigny). Sample no. 482.
30 *Lingulina dentaliniformis* Terquem. Sample no. 487.
31 *Lagena ovata* (Terquem). Sample no. 487.
32 *Astacolus filosa* (Terquem). Sample no. 477.
33 *Lenticulina varians* (Bornemann). Sample no. 482.
34 *Lenticulina quenstedti* (Gümbel). Sample no. 477.
35 *Epistomina parastelligera* (Hofker); a–c, dorsal, ventral and lateral views. Sample no. 482.
36 *Astacolus pellucida* Said and Barakat, n. sp.; paratype. Sample no. 482.
37 *Nonion jurassicum* Said and Barakat, n. sp.; a–c, dorsal, ventral and apertural views of holotype. Sample no. 484.
38 *Vaginulina constricta* (Terquem and Berthelin). Sample no. 487.
39 *Eoguttulina* cf. *polygona* (Terquem). Sample no. 477.
40 *Astacolus prima* (d'Orbigny). Sample no. 477.
41 Holothuroid remains.
42 Sponge spicules.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41b

The figured specimen is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. A few specimens of this species occur in the Bathonian of Gebel Maghara.

Family ROTALIIDAE

Genus CONICOSPIRILLINA Cushman, 1927

Conicospirillina planorbis Said and Barakat, **new species**
Plate 4, figure 10a–c

Test rounded, conical, consisting of one spirally coiled chamber; as many as three coils, increasing rapidly in breadth so that the last coil makes up one-half of the test; ventrally involute, only the last whorl visible, broadly umbilicate; spiral sutures faintly depressed and slightly distinct; wall calcareous, coarsely perforate; periphery subrounded; aperture slit-like, on the ventral face and extending along the tube. Diameter 0.25 mm.; height 0.01 mm.

This species is quite distinct because of its low cone, rapidly widening whorls, and large ventral umbilicus.

The holotype is from sample no. 485, along Wadi Horma, Gebel Maghara, northern Sinai. A few specimens of this species were found in the Kimmeridgian of Maghara.

Conicospirillina cf. **trochoides** (Berthelin)
Plate 4, figure 27a–c

Spirillina trochoides BERTHELIN, 1879, Rev. Mag. Zool., p. 37, pl. 1, figs. 20–22.

Test small, high conical, consisting of a single spirally coiled chamber; completely evolute on the dorsal side; ventral side flat and involute; wall calcareous, finely perforate; aperture a narrow slit on the ventral face of the revolving chamber, extending from the periphery toward the umbilicus.

This species is closely similar to *Conicospirillina trochoides* (Berthelin) except that it is slightly smaller and has more whorls on the dorsal side.

The figured specimen is from sample no. 484, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. Several specimens of this species were found in the Kimmeridgian of northern Sinai.

Genus TROCHOLINA Paalzow, 1922

Trocholina cf. **transversarii** Paalzow
Plate 3, figure 40a–b

Trocholina transversarii Paalzow. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 132, pl. 15A, fig. 3a–d.

Test free, small, conical, planoconvex; early whorls undivided, later ones usually divided into long chambers; wall calcareous, perforate; spiral sutures limbate; aperture elongate, at the base of the ventral side of the chamber.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai. A few specimens of this species were found in the Callovian of northern Sinai.

Genus PATELLINA Williamson, 1858

Patellina douvillei Said and Barakat, **new species**
Plate 2, figure 25a–c

Test free, small, high conical; early whorls indistinct, undivided, later ones usually divided into long chambers; chambers partially divided by internal septa, which are visible from the exterior, showing clearly in the last-formed chambers on the ventral side; somewhat umbilicate ventrally; wall somewhat thick, calcareous; aperture elongate, at the inner border of the chamber. Diameter 0.2 mm.; height 0.1 mm.

This species differs from *Patellina corrugata* Williamson in having a thicker wall, a higher spire, and less well developed internal septa.

The holotype is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai.

Genus DISCORBIS Lamarck, 1804

Discorbis dreheri Bartenstein
Plate 3, figure 41a–b

Discorbis dreheri Bartenstein. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 129, pl. 6, fig. 45a–b; pl. 8, fig. 42a–e; pl. 10, fig. 47a–d.

Test free, small, planoconvex; ventral side flattened and somewhat umbilicate, all chambers visible dorsally; sutures slightly distinct, depressed curved backward at the periphery; wall calcareous, surface smooth; aperture an elongate slit at the base of the last chamber.

This species belongs to the genus *Discorbis* as defined by Bermudez (1952). According to Hornibrook and Vella (1954), this species may belong to *Rosalina* d'Orbigny, 1826.

The figured specimen is from sample no. 489, Gebel Ingbashi, north of Bir Maghara, northern Sinai.

Genus EPISTOMINA Terquem, 1883

Epistomina costifera Terquem
Plate 1, figure 36a–b

Epistomina costifera Terquem. – BARTENSTEIN AND BRAND, 1937, Senckenb. Naturf. Ges., Abh., no. 439, p. 191, pl. 11B, fig. 30; pl. 11C, fig. 1.

Numerous specimens that belong to this species were separated from a sample at the contact between the Bajocian and Bathonian opposite Bir Maghara. This bed is usually referred to as Bajocian(?). The presence of *Epistomina costifera* Terquem in this bed suggests that the bed may belong to the upper Bajocian, since the first

appearance of this species is known from the corresponding Dogger in northwestern Germany.

The figured specimen is from sample no. 495, opposite Bir Maghara, northern Sinai.

Epistomina depressa Said and Barakat, **new species**
Plate 5, figure 22a–c

Test trochoid, depressed, biconvex; ventral side weakly umbilicate; periphery acute; chambers distinct, about six in the adult whorl, of uniform shape, increasing very gradually in size as added, very slightly inflated; sutures distinct, depressed, strongly oblique on the dorsal side, nearly radial on the ventral side; wall smooth and polished; aperture elongate, at the base of the last-formed chamber; supplementary lateromarginal apertures distinct, running parallel to the periphery on the ventral side. Diameter 0.28 mm.; thickness 0.15 mm.

The holotype is from sample no. 477, along Wadi Imshash Rashed, Gebel Melha, Maghara district, northern Sinai. A few specimens of this species were found in the Kimmeridgian of northern Sinai.

Epistomina parastelligera (Hofker)
Plate 3, figure 43; plate 5, figure 35a–c

Brotzenia parastelligera HOFKER, 1954, Palaeontographica, vol. 105, pt. A, p. 180, text-figs. 4–6.

Specimens that seem to be exactly identical to the typical form recorded recently by Hofker, mostly from the upper Dogger of northwestern Europe, are here found in the Callovian (lowermost Malm) of Sinai, as well as in the Kimmeridgian of the same locality.

The figured specimens are from sample no. 489 (pl. 3, fig. 43), Gebel Ingbashi, north of Bir Maghara; and from sample no. 477 (pl. 5, fig. 35), along Wadi Imshash Rashed, Gebel Melha, Maghara district; both in northern Sinai.

Phylum ECHINODERMATA

Class HOLOTHUROIDEA

Family STICHOPITIDAE

Genus STICHOPITES Deflandre-Rigaud, 1948

Stichopites mortenseni Deflandre-Rigaud
Plate 6, figures 6–10

Stichopites mortenseni Deflandre-Rigaud. – FRIZZELL AND EXLINE, 1955, Missouri School of Mines, Bull., Tech. ser., no. 89, p. 61, pl. 1, figs. 1–3.

Sclerite in the form of a simple, calcareous, translucent rod, circular in cross-section, tapering slightly and evenly from middle to bluntly rounded ends, bent near center. Length of specimen (fig. 6), 0.5 mm.; diameter 0.1 mm.

There is a slight modification of this form in which the sclerite becomes somewhat compressed, oval in cross section, and with acute periphery (fig. 8). This form is found in small numbers in the Bajocian.

The figured sclerites are from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. This form occurs in abundance in the Bajocian, and less frequently in the Bathonian, Callovian and Kimmeridgian of Gebel Maghara.

Genus CALCLIGULA Frizzell and Exline, 1955

Calcligula jurassica Said and Barakat, **new species**
Plate 6, figures 21a–b, 22

Sclerite calcareous, transculent, consisting of a solid circular rod that thickens on one side to form a depressed flaring disc, centrally perforate, and on the other side to form a depressed smaller structure. Length 0.33 mm.; diameter 0.05 mm. (fig. 21).

The holotype and paratype are from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. This form is rare in the Bajocian of Gebel Maghara, but is found in abundance in the Bathonian of the same locality.

Calcligula sp.
Plate 6, figure 23

Sclerite consisting of a circular though somewhat angled rod, ending in a club-shaped disc with three to four longitudinal grooves.

The figured sclerite is from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara.

Family CALCLAMNIDAE

Genus CALCLAMNA Frizzell and Exline, 1955

Calclamna(?) sp.
Plate 6, figure 15

Sclerite in the form of a rectangular plate with numerous circular depressions arranged in rows. This species is questionably assigned to this genus, as the plate is imperforate.

The figured specimen is from sample no. 22, from the Bajocian along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. Similar specimens were also found in the Bathonian of the same area.

Genus EOCAUDINA Martin, 1952

Eocaudina(?) sp.
Plate 6, figures 19–20

Sclerite in the form of miliary granules, usually replaced by iron oxide, mammillated, imperforate. These specimens are doubtfully assigned to this genus. They differ from the type in being imperforate. These fossils may not belong to the Holothuroidea.

The figured specimens are from sample no. 22 (fig. 19), along Wadi Maghara, 700 meters southwest of Bir Maghara; and from sample no. 477 (fig. 20), along Wadi Imshash Rashed, Gebel Maghara; both in northern Sinai. Specimens of this type are common in the Bajocian, Callovian and Kimmeridgian of Gebel Maghara and occur also rarely in the Bathonian of the same area.

Family ACHISTRIDAE

Genus ACHISTRUM Etheridge, 1881

Achistrum bartensteini Frizzell and Exline
Plate 6, figures 1–5

Achistrum bartensteini FRIZZELL AND EXLINE, 1955, Missouri School of Mines, Bull., Tech. ser., no. 89, p. 94, pl. 4, figs. 5–7.

Sclerite calcareous, translucent, in the form of an eye and shank. These specimens differ, however, from the forms described by Bartenstein (1936) in the absence of a spear and in having a centrally located eye. Diameter of ring 0.2 mm.; diameter of rod 0.05 mm. (fig. 1).

The figured specimens are from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. This form occurs in small numbers in the Bajocian and is found also in the Bathonian and Callovian of Gebel Maghara.

Family PRISCOPEDATIDAE

Genus PRISCOPEDATUS Schlumberger, 1890

Priscopedatus exlineae Said and Barakat, **new species**
Plate 6, figure 11

Sclerite cross-shaped, calcareous, translucent; arms tapering, circular in cross-section, equidimensional; disc possessing four diagonally placed incisions that bound a raised cross-shaped boss.

This species differs from *Priscopedatus bartensteini* (Deflandre-Rigaud) in being smaller, with equidimensional arms, and in having a much smaller disc and perforations.

The holotype is from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. This species is common in the Bajocian material studied.

Priscopedatus(?) frizzelli Said and Barakat, **new species**
Plate 6, figure 14

Sclerite in the form of a depressed table; outline variable; surface marked by numerous depressions arranged so as to give the table a honeycomb appearance; stirrup seven-footed, much depressed, small. This species is questionably assigned to the genus *Priscopedatus* because the sclerite seems to be imperforate and the stirrup is seven-footed.

The holotype is from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. This species is common in the Bajocian of Gebel Maghara, and is abundant in the Bathonian material of the same area.

Priscopedatus aegyptiacus Said and Barakat, **new species**
Plate 6, figures 24–27

Sclerite calcareous, consisting of a highly perforate table with spire, irregularly subcircular; perforations large, varying in size; stirrup four-footed.

PLATE 6

All specimens of holothuroid sclerites from the Jurassic of northern Sinai. All figures × 80.

1–5 *Achistrum bartensteini* Frizzell and Exline. Sample no. 22.

6–10 *Stichopites mortenseni* Deflandre-Rigaud. Sample no. 22.

11 *Pristopedatus exlineae* Said and Barakat, n. sp.; holotype. Sample no. 22.

12 *Annulina* cf. *metensis* Terquem. Sample no. 482.

13 Sclerite(?) from sample no. 22.

14 *Priscopedatus*(?) *frizzelli* Said and Barakat, n. sp.; holotype. Sample no. 22.

15 *Calclamna*(?) sp. Sample no. 22.

16–17 *Theelia sinaiensis* Said and Barakat, n. sp.; holotype and paratype. Sample no. 22.

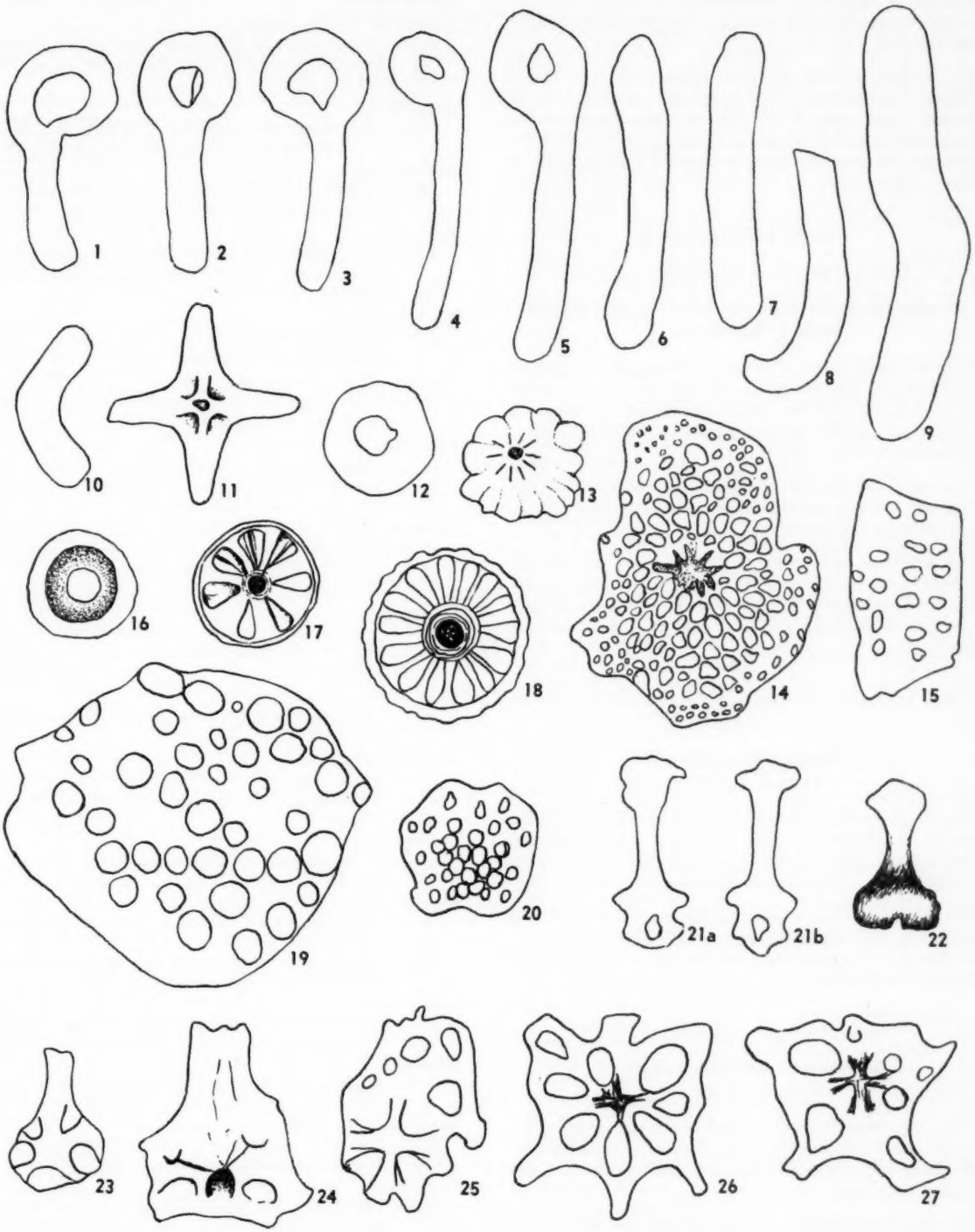
18 *Hemisphaeranthos* sp. Sample no. 22.

19–20 *Eocaudina*(?) sp. Sample no. 22 (fig. 19); sample no. 477 (fig. 20).

21–22 *Calcligula jurassica* Said and Barakat, n. sp.; holotype and paratype. Sample no. 429.

23 *Calcligula* sp. Sample no. 429.

24–27 *Priscopedatus aegyptiacus* Said and Barakat, n. sp. Sample no. 429.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This species is similar to *Priscopedatus pyramidalis* Schlumberger except for the absence of a marginal row of perforations.

The figured sclerites are from sample no. 429, Gebel Somor, northwest of Bir Maghara, northern Sinai. Several specimens of this species were found in the Bathonian of Gebel Maghara. They occur also in lesser frequency in both the Bajocian and the Callovian of the same area.

Family THEELIIDAE

Genus THEELIA Schlumberger, 1890

Theelia sinaiensis Said and Barakat, **new species**
Plate 6, figures 16–17

Sclerite in the form of a seven-spoked wheel; outline rounded, rim thin, periphery smooth; spokes moderately wide, flat, with vertical sides; interspoke spaces solid, triangular; central portion small, circular, depressed. Diameter 0.2 mm. (fig. 17).

This species differs from *Theelia angulata* (Deflandre-Rigaud) in being much smaller, in having seven spokes, and in being less arched.

The holotype and paratype are from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. Sclerites of this species are common in the Bajocian and Bathonian of Gebel Maghara.

Genus HEMISPHAERANTHOS Terquem and Berthelin, 1875

Hemisphaeranthos sp.
Plate 6, figure 18

Sclerite in the form of a wheel with fourteen to sixteen spokes; rim inclined to plane of wheel, curving upward and inward, slightly dentate, teeth not pronounced; central portion imperforate. Diameter 0.25 mm.

The figured sclerite is from sample no. 22, along Wadi Maghara, 700 meters southwest of Bir Maghara, northern Sinai. A few specimens of this species occur in the Bajocian of Maghara.

Genus ANNULINA Terquem, 1862

Annulina cf. **metensis** Terquem
Plate 6, figure 12

This ring-shaped structure has been previously described as a foraminifer from the Kimmeridgian of Gebel Maghara (see above). It may be a holothuroid of the family Theeliidae.

The figured specimen is from sample no. 482, along Wadi Imshash Rashed, Gebel Maghara, northern Sinai. (See also pl. 4, fig. 13.)

BIBLIOGRAPHY

ARKELL, W. J., AND OTHERS
1952 – *Jurassic ammonites from Gebel Tuwaiq, central Arabia.* Roy. Soc. London, Philos. Trans., ser. B, vol. 236, pp. 241–313.

BARNARD, T.
1950 – *Foraminifera from the lower Lias of the Dorset coast.* Geol. Soc. London, Quart. Jour., vol. 105, pp. 347–388.

BARTENSTEIN, H.
1936 – *Kalk-Körper von Holothurien in norddeutschen Liasschichten.* Senckenbergiana, vol. 18, no. 1–2, pp. 1–10.

BARTENSTEIN, H., AND BRAND, E.
1937 – *Mikropaläontologische Untersuchungen zur Stratigraphie des nordwestdeutschen Lias und Doggers.* Senckenb. Naturf. Ges., Abh., no. 439.

BARTHOUX, J. C.
1922 – *Chronologie et description des roches ignées du Désert Arabique.* Inst. Égypte, Mém., vol. 5.

BARTHOUX, J. C., AND DOUVILLÉ, H.
1913 – *Le Jurassique dans le désert à l'est de l'isthme de Suez.* Acad. Sci., C. R., vol. 157, p. 265.

BERMUDEZ, P. J.
1952 – *Estudio sistemático de los foraminíferos rotaliformes.* Venezuela, Minist. Minas e Hidrocarb., Bol. Geol., vol. 2, no. 4, pp. 3–230, pls. 1–35.

BRONNIMANN, P.
1955 – *Microfossils incertae sedis from the Upper Jurassic and Lower Cretaceous of Cuba.* Micropaleontology., vol. 1, pp. 28–51.

COLOM, G.
1955 – *Jurassic-Cretaceous pelagic sediments of the western Mediterranean zone and the Atlantic area.* Ibid., vol. 1, pp. 109–123.

CUVILLIER, J.
1951 – *Corrélations stratigraphiques par microfaciès en Aquitaine occidentale.* Leiden: Brill.

DEFLANDRE-RIGAUD, M.
1946 – *Sur les divers types de sclérites d'holothurides oxfordiens des marnes de Viller-sur-Mer.* Acad. Sci., C. R., vol. 223, pp. 513–515.

DOUVILLÉ, H.
1916 – *Les terrains secondaires dans le massif du Moghara.* Acad. Sci., Mém., ser. 2, vol. 54.

FRIZZELL, D. L., AND EXLINE, H.
1955 – *Micropaleontology of holothurian sclerites.* Micropaleontology, vol. 1, pp. 335–342.
1955 – *Monograph of fossil holothurian sclerites.* Missouri School of Mines, Bull., Tech. ser., no. 89.

HAEUSLER, R.
1890 – *Monographie der Foraminiferenfauna der Schweizerischen Transversarius Zone.* Schweiz. Pal. Ges., Abh., vol. 17.

HENSON, F. R. S.
1948 – *Foraminifera of the genus Trocholina in the Middle East.* Ann. Mag. Nat. Hist., ser. 11, vol. 14 (1947), p. 445.

HORNIBROOK, N. DE B., AND VELLA, P.
1954 – *Notes on the generic names of some rotaliform foraminifera.* Micropaleontologist, vol. 8, no. 1, pp. 24–28.

HUME, W. F.
1921 – *The Jurassic and Lower Cretaceous rocks of northern Sinai.* Geol. Mag., vol. 57, pp. 339–347.

JEANNET, A.
1937 – *Tableaux stratigraphiques.* Zürich.

TABLE 1

DISTRIBUTION AND FREQUENCY OF FORAMINIFERA

	Bajocian	Bathonian	Callovian	Kimmeridgian
Agathammina antiqua			⊖	⊖
Ammobaculites cobbani	⊙			
Ammobaculites elegantissima				○
Ammobaculites fontinensis		○	⊖	
Ammobaculites glaessneri				⊖
Ammobaculites magharaensis				⊖
Ammomarginulina pellucida				⊖
Ammodiscoides magharaensis			⊙	⊙
Annulina cf. *metensis*				○
Arenovirgulina aegyptiaca			○	
Astacolus crepidula	⊖		⊖	⊙
Astacolus filosa	○		⊙	⊙
Astacolus inaequistriata	○			
Astacolus matutina	○			
Astacolus minuta			○	
Astacolus pellucida			⊖	○
Astacolus prima	⊙	⊙		⊙
Astacolus stilla	⊙			
Astacolus sp.			○	
Bathysiphon sp. 1			⊖	
Bathysiphon sp. 2				○
Bolivina bartensteini				⊖
Bolivina sp.			○	
Bulbobaculites sp.			○	
Citharina clathrata	○			
Citharina flabelloides				○
Citharina inconstans				○
Conicospirillina planorbis				⊖
Conicospirillina cf. *trochoides*				⊖
Cornuspira orbicula		⊖		
Dentalina arbuscula		○		
Dentalina crenata	○			
Dentalina pseudocommunis			⊖	⊖
Dentalina sinemuriensis		○		○
Dentalina torta				⊖
Dentalina vetustissima			○	○
Discorbis dreheri			○	
Dorothia terquemi				⊖
Ellipsoglandulina sp.		○		
Eoguttulina polygona	○		⊖	○
Epistomina costifera	○			
Epistomina depressa				○
Epistomina parastelligera			⊖	⊖
Frondicularia lignaria	○			
Frondicularia spissa			○	○
Glomospira compacta				⊙
Glomospira jurassica				⊖
Haplophragmoides barthouxi		⊙		
Haplophragmoides sp.				○
Hemicristellaria vestuta	⊖			⊙
Hyperammina sp. 1			○	
Hyperammina sp. 2				⊖
Involutina aspera	○			
Involutina gaultina			○	
Involutina magharaensis	○			⊙
Lagena ovata	○			⊖
Lenticulina acutiangulata	○			
Lenticulina magharaensis				⊖
Lenticulina muensteri	⊖		⊖	⊖
Lenticulina quenstedti			⊖	○
Lenticulina subalata	○	⊖	⊙	⊙
Lenticulina subalata var.	○			
Lenticulina tricarinella			⊙	
Lenticulina varians	⊙	○	⊖	⊖
Lenticulina sp.			○	⊖
Lingulina cernua			⊖	
Lingulina dentaliniformis				○
Lingulina lanceolata			⊖	⊙
Lingulina minuta			○	
Lingulina pupa		○		
Lingulina sp.	○			
Lituotuba sp.				○
Lituola sp.	○			
Marssonella oxycona			○	⊖
Marginulina oolithica	○			○
Marginulina simplex	○	⊖	○	○
Marginulina sp.	○			
Massilina sp.	○			
Miliammina cf. *valdensis*				○
Nodosaria crispata	○	⊖	○	○
Nodosaria dolioligera		○		
Nodosaria fontinensis		⊖		
Nodosaria metensis	○			○
Nodosaria mitidana				⊖
Nodosaria mitis		○		
Nodosaria opalini		○		
Nodosaria simplex		⊖		⊖
Nodosinella brandi				○
Nonion jurassicum				⊙
Orthomorphina terquemi			⊖	⊙
Paleogaudryina magharaensis			⊖	⊙
Patellina douvillei		⊖		
Planularia cordiformis		○		○
Proteonina difflugiformis	⊙		⊖	⊖
Proteonina sp. 1			⊖	
Proteonina sp. 2				○
Quinqueloculina compressa		⊙		
Rectoglandulina abbreviata		⊖		
Rectoglandulina hofkeri				⊖
Rectoglandulina humilis		⊖		
Rectoglandulina tenuis	○			
Rectoglandulina vulgata				⊖
Reophax barnardi				⊖
Reophax metensis			⊙	
Reophax scorpiurus				○
Rhabdammina aegyptiaca				○
Rhabdammina sp.			○	
Saracenaria aegyptiaca				○
Saracenaria cornucopiae				○
Saracenaria triangularis		○	○	○
Saracenaria sp.				○
Sigmoilina sp.			○	
Spiroloculina sp.		○		
Spiroplectammina biformis		○		
Spirophthalmidium concentricum			○	○
Trochammina bartensteini	⊙			
Trochammina depressula				○
Trochammina douvillei				○
Trocholina transversarii			○	
Vaginulina constricta	○	○		⊖
Vaginulina legumen		⊖		
Vaginulina sp.				○
Vaginulinopsis bartensteini			⊖	
Vaginulinopsis misrensis				⊖
Verneuilinoides attenuata				○
Verneuilinoides loeblichi				⊖
Verneuilinoides minuta				○
Verneuilinoides sp.			○	

○ = few ⊖ = common ⊙ = abundant

KUHN, O.
1935 – *Die Fauna des untersten Lias (Gibbosus-Zone) aus dem Sendelbach im Hauptmoorwald östlich Bamberg.* Neues Jahrb. Min. Geol. Pal., vol. 73, pt. B, pp. 465–493.

LOMBARD, A.
1945 – *Attribution de microfossiles du Jurassique supérieur à des Chlorophycées (Proto- et Pleurococcacées).* Eclogae Geol. Helv., vol. 38, pp. 163–173.

MACFADYEN, W. A.
1935 – *Jurassic foraminifera.* In: *The geology and palaeontology of British Somaliland.* London: Government of the Somaliland Protectorate, pt. 2, pp. 7–20.

MAYNC, W.
1952 – *Critical taxonomic study and nomenclatural revision of the Lituolidae based upon the prototype of the family, Lituola nautiloides Lamarck, 1804.* Cushman Found. Foram. Res., Contr., vol. 3, pp. 35–56.

MOHLER, W.
1938 – *Mikropalaeontologische Untersuchungen in der nordschweizerischen Juraformation.* Schweiz. Pal. Ges., Abh., vol. 60.

MOON, F. W., AND SADEK, H.
1921 – *Topography and geology of northern Sinai.* Egypt, Survey Dept., Pet. Res. Bull., no. 10.

MÜNSTER, G. VON
1843 – *Über einige Theile fossiler Holothurien im Jura-Kalk vom Streitberg.* Beitr. Petref.-Kunde, vol. 6, pp. 92–93.

ROEMER, F. A.
1836 – *Die Versteinerungen des norddeutschen Oolithengebirges.* Hannover.

SADEK, H.
1925 – *The distribution of the Jurassic formations in Egypt and Sinai.* Congr. Internat. Géol., Liége, C. R., pp. 1039–1048.

SAID, R., AND BARAKAT, M. G.
[MS.] *Cenomanian microfossils from northern Sinai, Egypt.* Egyptian Jour. Geol., vol. 1 (in press).

SAID, R., AND KENAWY, A.
1956 – *Upper Cretaceous and Lower Tertiary foraminifera from northern Sinai, Egypt.* Micropaleontology, vol. 2, pp. 105–173.

SCHWAGER, C.
1865 – *Beitrag zur Kenntnis der mikroskopischen Fauna jurassischer Schichten.* Ver. Vaterl. Naturk. Württemberg, Jahreshefte, vol. 21, pp. 81–151.
1866 – *Foraminiferen der Transversariuszone.* Geogn.-Pal. Beitr., vol. 1, no. 2.
1867 – *Foraminiferen der Zone des Ammonites sowerbyi.* Ibid., vol. 1, no. 3.

SHATA, A.
1951 – *The Jurassic of Egypt.* Inst. Désert d'Égypte, Bull., vol. 1, no. 2, pp. 68–73.

TERQUEM, O.
1858 – *Mémoire sur les foraminifères du Lias du département de la Moselle; Partie I.* Acad. Imp. Metz, Mém., vol. 39 (ser. 2, vol. 6) (1857–1858), pp. 563–654, pls. 1–4.
1862 – *Recherches sur les foraminifères du Lias; Second mémoire.* Acad. Imp. Metz, Mém., vol. 42 (ser. 2, vol. 9) (1860–1861), pp. 415–466, pls. 5–6.
1864*a* *Troisième mémoire sur les foraminifères du Lias.* Acad. Imp. Metz, Mém., vol. 44 (ser. 2, vol. 11) (1862–1863), pp. 361–438, pls. 7–10.
1864*b* *Quatrième mémoire sur les foraminifères du Lias.* Metz: Lorette, pp. 233–308, pls. 11–14.
1866*a* *Cinquième mémoire sur les foraminifères du Lias.* Metz: Lorette, pp. 313–454, pls. 15–18.
1866*b* *Sixième mémoire sur les foraminifères du Lias.* Metz: Lorette, pp. 459–532, pls. 19–22.
1870*a* *Deuxième mémoire sur les foraminifères du Système Oolithique.* Acad. Imp. Metz, Mém., vol. 50 (ser. 2, vol. 17) (1868–1869), pp. 403–456, pls. 9–21.
1870*b* *Troisième mémoire sur les foraminifères du Système Oolithique.* Acad. Imp. Metz, Mém., vol. 51 (ser. 2, vol. 18) (1869–1870), pp. 299–380, pls. 22–29.
1877 – *Recherches sur les foraminifères du Bajocien de la Moselle.* Soc. Géol. France, Bull., sér. 3, vol. 4 (1876), no. 7, pp. 477–500.

ABSTRACT: Wechesia pontis, *n. gen. and n. sp. (new family Wechesiidae), is based on the first recorded fossil crustacean gastroliths. These minute objects (less than 0.5 mm. in diameter), planoconvex, finely laminar, and calcareophosphatic, originated in larval marine crayfish. Gastroliths are stratigraphically unimportant, but are significant in paleoecology and in their bearing on crustacean evolution and migration. Summary accounts are given of gastroliths of the crayfish* Astacus *(from Huxley) and of the lobster* Homarus *(from Herrick), and those of a Mid-Western crayfish* ("Cambarus") *are described and figured.*

Crustacean gastroliths from the Claiborne Eocene of Texas

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INTRODUCTION

Gastroliths ("gizzard stones," "stomach stones," or "crab's-eyes") are paired calcareophosphatic accretions formed within the bodies of lobsters and crayfish immediately prior to ecdysis (molting). Ranging from about 5 mm. to more than 25 mm. in greater diameter, they are elliptical to circular or heart-shaped in outline and plano- or concavo-convex in profile. Two distinctive internal structures are known: (1) a spicular organization within the gastrolith that falls apart on removal from its containing sac, and (2) a thinly laminar construction parallel to the external surface of the gizzard stone. Only the latter is susceptible to fossilization.

The existence of gastroliths within the body is temporary. During molting, they pass into the gizzard, are ground down, and are assimilated; they do not accompany the shed carapace. Intervention by a predator, consuming the pre-molt animal, normally is required for deposition of the gastrolith in sediments. This role is played occasionally by fish and, according to F. A. Chace, Jr. (letter dated August 29, 1957), by certain wild ducks that use gastroliths as their own gizzard stones. The function of gastroliths has been argued. Storer (1943, p. 443) accepts the old idea that they serve as storage bodies for materials needed to harden the post-ecdysial carapace. Herrick (1911, p. 209), however, stressed the inadequacy of this supply, regarding gastroliths as excretion products — repositories for lime salts resorbed previous to molting, their redeposition in the exoskeleton being of minor importance.

Gastroliths are known with certainty only in decapod crustaceans of the superfamily Nephropsidea (suborder Reptantia, section Macrura), which includes the marine lobsters (family Nephropsidae = Homaridae) and the fresh-water crayfish of the Northern Hemisphere (family Astacidae = Potamobiidae) and of the Southern Hemisphere (family Parastacidae). Herrick (1911, p. 208) quotes at third hand a record of gizzard stones in a Jamaican land crab, but Chace (in correspondence) indicates that this occurrence has not to his knowledge been verified. Very extensive study has been given to the decapod crustaceans because of their economic importance, and the absence of gastroliths in commercially valuable groups would seem to be established. The possibility cannot be denied, of course, that some rare or little-known prawn, shrimp, or crab might also secrete them.

It is unfortunate that the word "gastrolith" has been widely and exclusively applied, in geological circles, to the polished pebbles associated with saurian remains (compare Howell, 1957). The term clearly has priority in carcinology, and it could not reasonably be replaced by the obsolete vernacular name "crab's-eyes," the awkward and ambiguous expression "gizzard stones," or the outmoded pharma-

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ceutical Latin terms "*oculi cancrorum*" and "*lapides cancrorum.*" Confusion can be avoided by the use of the qualified *crustacean gastroliths* and *saurian gastroliths.*

Fossil crustacean gastroliths, as far as we are aware, are recorded here for the first time. The known examples are minute, presumably having come from planktonic larval forms of a marine crayfish related to the astacids and parastacids of the Recent fauna. They are important in supporting Huxley's (1895) hypothesis of the marine origin of fresh-water crayfish, showing the existence during the Eocene of a marine astacomorph family closely related to the present continental groups. Of little practical use in stratigraphy because of their rarity, their application in micropaleontology should be in the field of paleoecology.

ACKNOWLEDGMENTS

We are indebted to Dr. Samuel P. Ellison, Jr., of the University of Texas (Austin), for calling to our attention the locality near Bryan, Texas. Dr. Henryk B. Stenzel, currently with the Shell Development Company, Houston, Texas, has given indispensable information about the stratigraphy of the area and concerning fossil crustaceans. Dr. Fenner A. Chace, Jr., Curator of the Division of Marine Invertebrates, U. S. National Museum (Washington, D.C.), supplied an essential reference and contributed data regarding Recent crustaceans and their classification; and Dr. Harold K. Brooks, of the University of Florida (Gainesville), has contributed helpful information. The illustrations in text-figure 1 were drawn by Robert C. Thornton, a student at the Missouri School of Mines.

GASTROLITHS OF RECENT CRAYFISH

The fresh-water crayfish (family Astacidae), a certain seasons, has a pair of strongly calcified structures in the walls of the anterior gizzard. They are plano- or concavo-convex, the flat or depressed side being attached to the chitinoid inner wall. The rounded surface faces outward, although extending onto the inner side, and is covered by the soft "true wall" of the gizzard. A narrow channel separates the flattened attachment scar from the interior extension of the rounded outer surface. Transverse thin sections show the structure to consist of numerous thin layers, the inner being parallel to the flat internal surface, the outer conforming to the contour of the external side (Huxley, 1895, pp. 30, 348, text-fig. 7d). These stones may attain a diameter as great as 8 mm. (An excellent account of the morphology and position of the gastrolith of the crayfish has been given by Huxley, 1895, pp. 347–349.)

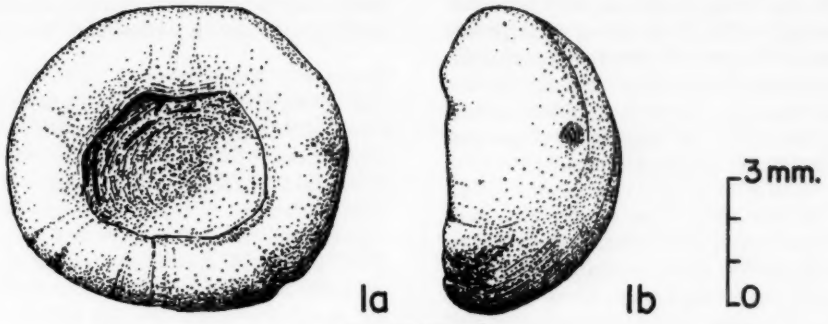
The gastrolith is predominantly calcareophosphatic, an analysis showing the following constituents (Huxley, 1895, p. 530; terminology revised):

	Per cent
Water-soluble organic material	11.43
Organic material insoluble in water ("probably chitin")	4.33
Calcium phosphate	18.60
Calcium carbonate	63.16
Sodium, presumed to be carbonate	1.41
	98.93

Gastroliths develop from ten to forty days before ecdysis. When shed into the gizzard during molting, they are ground down and absorbed, disappearing within a period of twenty-four to eighty hours. The time-lapse between initiation and destruction increases with the age of the individual.

The life history of the crayfish is basically similar to that of the lobster, except that the individual hatches in a form suggesting the fourth stage of the latter (Herrick, 1911, pp. 167–168). Retention of the uncalcified larval forms within the egg, in the fresh-water crayfish, is a modification required by a fluviatile existence, where planktonic stages would be hazardous. According to Huxley (1895, p. 350), the crayfish molts eight times in its first year (five times during July to September, thrice during the subsequent May to July). Ecdysis occurs five times in the second year (August, September, May, June, and July), and twice in the third year (July and September). During the fourth and subsequent years, females molt once (August–September) and males twice (June-July and August-September).

Astacus fluviatilis, the common European crayfish, has a characteristic gastrolith (Huxley, 1895, pp. 29–31). It is large (reaching a diameter of 5.4 mm.), relatively thin (ratio of thickness to diameter 33%), and subcircular. On the interior, the attachment scar is flat or depressed and the peripheral margin very narrow. The nature and position of the channel are not evident. The convex exterior surface is sculptured with irregular prominences described as "something like a 'brain-stone' coral." No information is available regarding ontogenetic or other variability of the gastrolith of this species, except for the increase in convexity with growth shown in vertical section, nor are data given concerning interspecific differences within the genus.



TEXT-FIGURE 1
Gastrolith of Recent fresh-water crayfish (*"Cambarus"*): a, interior surface; b, side view.

A pair of gastroliths of "*Cambarus*" sp. (text-fig. 1a–b) were taken from the alimentary tract of a trout at Montauk Park, Missouri, on June 24, 1957. They are identical: Large (greater diameter 8.1 mm.), broadly and evenly elliptical (ratio of lesser diameter to greater diameter 90%), and thick (ratio of thickness to greater diameter 54%). The inner side is marked by the depressed, shallowly concave attachment scar, which is separated from the peripheral margin by a very narrow and inconspicuous channel. The scar is sculptured by a few impressed lines and a plexus of very fine raised threads. The channel is situated beneath the overhanging inner wall of the peripheral margin and lies in the plane of that wall. The peripheral margin is relatively wide, gently undulating, and marked by irregularly disposed shallow, narrow, radial grooves. The domed external side is smooth and polished, marked only by shallow furrows of inconsistent position. (Dissection of six small to medium sized and three large crayfish on July 13, 1957, failed to yield gastroliths. As a consequence, we have no data on variation and ontogenetic stages.)

GASTROLITHS OF THE LOBSTER

The gizzard stones of the American lobster (*Homarus americanus* Milne Edwards), the commercial marine species of the East Coast, have been described by Herrick (1911, p. 209):

"If the shell of the lobster which is nearly ready to molt is removed, there will be seen two glistening snow-white masses, one on either side of the stomach. A gastrolith taken from a lobster 11 inches in length was an inch long, three-quarters of an inch wide, and a quarter of an inch thick. Its outer convex side was applied to the sac in which it lay, while its concave side was separated from the cavity of the stomach by the old cuticular lining of this organ. When the stomach is raised the gastroliths almost break through its delicate outer wall by their own weight. They lie between the old cuticular lining of the stomach, which may be stripped off, and its delicate outer wall, next to the body cavity. The impression of the gastrolithic plate. . . is seen on the new cuticular lining only. *If the sacs in which they are formed are cut open, each mass separates into hundreds of small ossicles or columns, the majority of which are slender truncated prisms of irregular shapes and about one-fifth of an inch long. Each ossicle resembles a piece of milk-white glass, with transparent and longitudinal striations, like those seen in the cuticle.*" [Italics by D. L. F. and H. E.]

The sequence of molts in the ontogeny of the lobster is essentially like that of the crayfish, except that three earlier stages are present. At the fourth stage (following the fourth molt), the juvenile lobster has undergone an abrupt metamorphosis, and has changed at once to its adult form. The lobsterling has reached a body length of about 11 or 12 millimeters (Herrick, 1911, pl. 30, figs. 2–3), its exoskeleton has become calcified, and it is ready or nearly ready to desert the free-swimming existence for a life among the rocks and crevices of the bottom, where it lives from the fifth stage on. The fourth molt marks the initiation of hard preservable structures and the last stage of light-seeking and a planktonic position in the sea. It is the one time in the life of the lobster when consistent activity at the surface is the rule. (The foregoing is an extremely abbreviated account from Herrick's monograph.)

FOSSIL GASTROLITHS

Crustacean gizzard stones from the Claiborne beds of central Texas are minute, ranging from 0.20 to 0.35 mm. in diameter. Structurally identical with

the gastroliths of the Recent crayfish, they have the same plano-convexity, fine lamination, attachment scar, and channel, although differing in the sculpture and profile of the external surface and in the inclination of the channel. Their internal structure differs markedly from the loose aggregate of spicules making up the gastrolith of the lobster.

These gastroliths resemble some extremely rare fossil ossiculiths associated with them in the Weches formation, and a very few of the ossiculiths from the sacculus and lagena of living fishes. They are comparable in size and shape, and the channel of the gastrolith is analogous to the incised line of the plano-convex ossiculith (compare Frizzell and Exline, 1958, text-figs. 4–7). These resemblances are superficial rather than basic, for the majority of Recent ossiculiths have random for even in a single fish, lacking the consistent structure of the crustacean gizzard stones. Moreover, the ossiculith is calcareous, rather than calcareophosphatic, and does not have the very fine lamination of the gastrolith. Similarity of the two structures results from an identical mechanism of secretion: formation beneath a flexible membrane, or within a pocket in it, plano-convexity increasing as the secreting layer is pushed outward by the accumulating mass of stony material.

The fossil gastroliths are believed to have come from larval individuals of a marine relative of the fresh-water crayfish, probably from an extinct family. By analogy with the development and habits of the American lobster, the fourth molt stage is postulated. The ratio of the body length of Recent lobster and crayfish to their respective gastroliths ranges roughly from 11:1 to 13:1. Applying these ratios to the fossils, the Eocene gastroliths seem to have originated in larval forms not less than 2.1 mm. nor more than 4.5 mm. long. Although this suggested length is appreciably less than that recorded for the juvenile lobster (less than one-half to one-fourth), the smaller adult size expected in a crayfish might be reflected in smaller larval forms.

Marine crayfish with characteristics of the Astacidae are report ed by Huxley (1895) from strata of Jurassic and Cretaceous age. He believed that fresh-water crayfish originated during the Cenozoic, and were derived from widespread marine ancestors. Sakakura (1939), however, has recorded a parastacoid "fresh-water crayfish" from Mesozoic beds in Manchuria. The Claiborne gastroliths are compatible with Huxley's hypothesis, or they could be descendents of an earlier ancestral stock. In either case, we do not consider them identifiable to family, in a zoological sense, and we are proposing a familial unit based entirely on discrete gastroliths.

Gastroliths are extremely rare microfossils in the Claiborne greensands. Our suite of ten specimens resulted from many hours of intensive search through the fraction of washed residues held between sieves of 60 and 80 meshes per inch. This rarity of specimens does not reflect the abundance of the contributing crustaceans in the Eocene sea (compare Brooks, 1957, p. 896). Gastroliths presumably were present, as in the living crayfish, for a very small part of the life span, and were not left with the molted exoskeleton. Their preservation demanded that the crustacean be eaten (probably by a fish), and that its gizzard stones pass unscathed through the alimentary tract of the predator. Finally, the gastroliths must have escaped digestion by the abundant mud-eaters of the bottom sediments (see Stenzel and others, 1957, pp. 26–31). From the fact that Recent crab's-eyes formerly had a wide medicinal use as an antacid, we suppose that escape from attrition and solution by digestive juices in predator or scavenger could have occurred only rarely.

DESCRIPTIONS OF LOCALITIES

(1) Middle Eocene, Claiborne group, Cook Mountain formation, Wheelock member: Burleson County, Texas, boundary with Brazos County; bank of Brazos River immediately east of bridge on Texas Highway no. 21, 10.4 miles by speedometer west of city limits of Bryan; dark, very abundantly glauconitic, extremely fossiliferous silty shale. Collected by D. L. and H. E. Frizzell, October 19, 1951.

A later trip to the outcrop (D. L. Frizzell, August 16–17, 1957) showed the sample to have come from Stenzel's (1935) "bed (ad.)" roughly 4 to 8 feet above a broad bench marking the top of the Stone City beds. Stenzel described the unit as: "Glauconite; green, commonly red-brown and weathered, massive, marly, fossiliferous, with occasional limonite concretions." When last visited, the Wheelock beds were covered by silt deposits left by the floods of 1957, but the prominent bench below them showed beyond question the stratigraphic position of our original sample.

The locality is famous under several names: Moseley's Ferry (and Moseley's Bluff), San Antonio Ferry, and Stone City Bluff (Renick and Stenzel, 1931; Stenzel, 1935; Stenzel and others, 1957). Locally, it has been known informally as "Whiskey Bridge" (S. P. Ellison, Jr., oral communication, October, 1951). This important outcrop is described

in detail by Stenzel, Krause, and Twining in their monograph on the pelecypods of the Stone City beds.

(2) Middle Eocene, Claiborne group, Weches formation, Viesca member: The locality originally was described as: Smithville, Bastrop County, Texas; south bank of Colorado River, about 0.1 mile west of highway bridge; highly glauconitic shale near base of exposure, about two feet stratigraphically below an indurated stratum with abundant pelecypods; collected by Helen J. Plummer, D. L. Frizzell, and H. E. Frizzell, March 3, 1946.

Smithville was revisited in August, 1957, by D. L. Frizzell. The site is a short distance *east* of the present bridge on Texas Highway no. 71. It is closed to public entry, and the outcrop apparently was covered by the silt and debris of floods early in the year. H. B. Stenzel (oral statement, August, 1957) reports that even before 1957 the outcrop was largely silted over and obscured by vegetation. Consequently, this classical collecting area has become unavailable to paleontologists.

SYSTEMATIC DESCRIPTIONS

Phylum ARTHROPODA

Class CRUSTACEA

Subclass MALACOSTRACA

Series EUMALACOSTRACA

Superorder EUCARIDA

Order DECAPODA

Suborder REPTANTIA

Section MACRURA

Superfamily NEPHROPSIDEA

Family **Wechesiidae** Frizzell and Exline, **new family**

Diagnosis: Gastroliths of nephropsidean crustaceans; plano- or concavo-convex, outline variable (circular, elliptical, or cordiform); external surface moderately to strongly inflated, smooth or sculptured, sometimes with a central depression; internal surface with a central attachment scar, a peripheral border, and a marked channel separating scar and border; attachment scar flat or slightly concave, flush with border or depressed; channel possibly of variable inclination; calcareophosphatic, very thinly laminar, laminae grading from plane of attachment scar to parallel with external surface; minute in known fossils (less than 0.5 mm.), presumably ranging to several centimeters in diameter.

Remarks: The family Wechesiidae is proposed primarily for use in micropaleontology. Its zoological affinities may never become established, although, as indicated by the internal lamination, it is more closely related to the Astacidae (and Parastacidae?) than to the Nephropsidae. The family and its single known genus are more or less artificial units. Species based upon gastroliths should be natural units but impossible to associate with nominal species established upon the entire or fragmental carapace. The new species, genus, and family therefore are essentially parataxa (Hemming, 1957; Moore and Sylvester-Bradley, 1957), although — to insure their nomenclatural validity! — they are proposed as Linnean categories. (The nomenclature of discrete fragments has recently been discussed by Frizzell and Exline, 1956, pp. 52–58; Hemming, 1957; Moore and Sylvester-Bradley, 1957; Müller, 1956, pp. 1327–1331; and Kozlowski, 1956, pp. 172–174.)

Generic characters within the Wechesiidae may be suggested, subject to verification when new material is found. The position of the channel on the internal surface may be a valid distinction. Possibly the sculpture and contour of the external surface might separate recognizable species-groups.

Genus **Wechesia** Frizzell and Exline, **new genus**

Type species: Wechesia pontis Frizzell and Exline, n. sp.

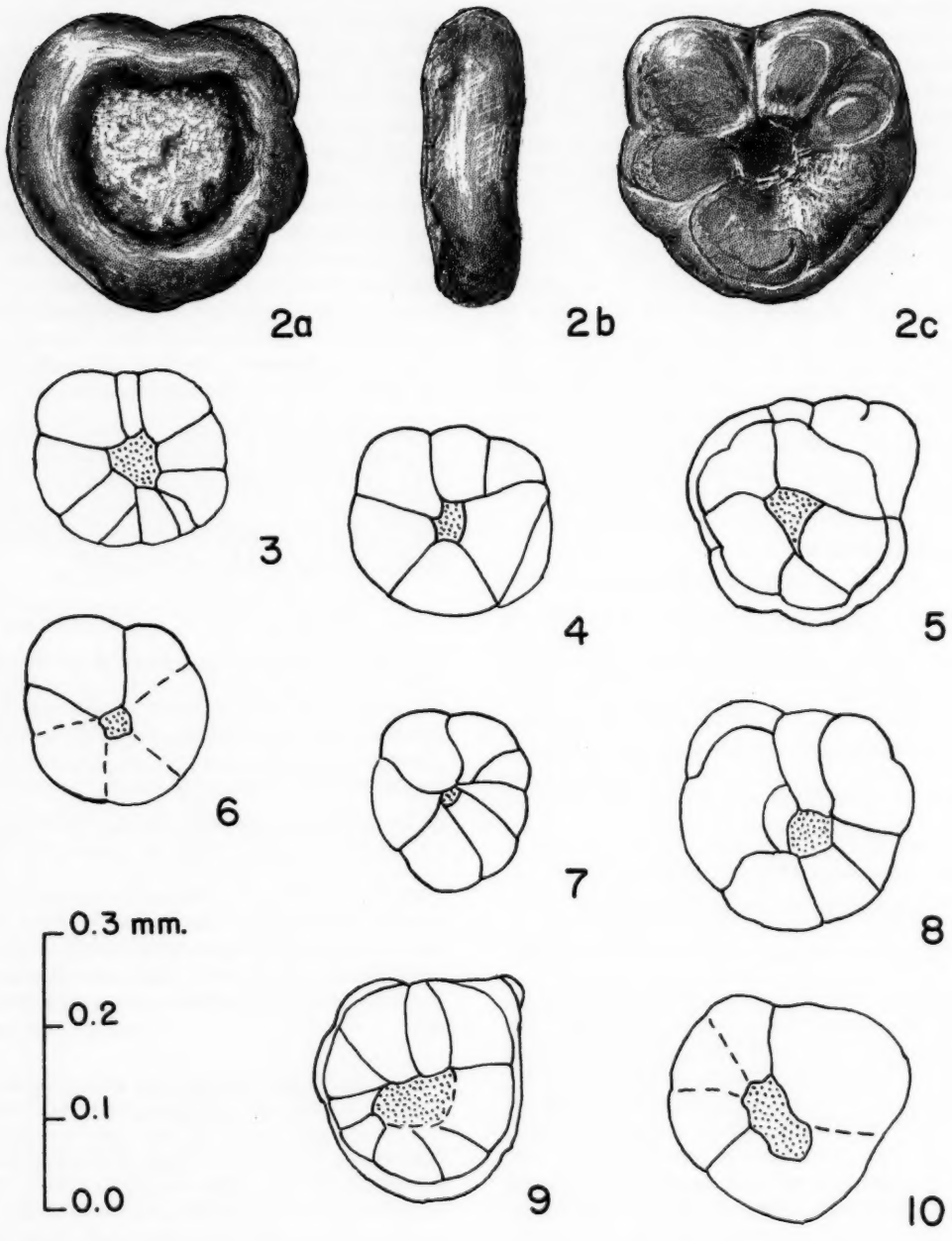
Description: Minute (diameter 0.20 to 0.35 mm.); external surface polished, sculptured with radial grooves and central depression; channel of internal surface normal to plane of attachment scar.

Range and distribution: The genus is known only from the Claiborne group (Middle Eocene) of Texas.

Remarks: Wechesia is extremely rare, even in the samples from which it has been obtained. It should be sought in the finer-screen fractions of residues from heavily glauconitic and abundantly fossiliferous siltstones and shales of pre- and post-Eocene age.

Wechesia pontis Frizzell and Exline, **new species**
Text-figures 2–10

Description: Gastrolith minute (0.19 to 0.34 mm. in greater diameter, typically 0.26 mm.), relatively thin; outline irregularly cordiform but variable, periphery unevenly scalloped and sometimes with an unequally developed flange; internal surface flat to slightly depressed, channel deep and wide; external surface sculptured with large, deep central depression surrounded by inflated areas; depression



TEXT-FIGURES 2–10

Wechesia pontis Frizzell and Exline, n. sp.: 2a–c, interior, side, and exterior views of holotype; 3–10, outline sketches of exterior of paratypes, showing variability of the species.

subcircular to polygonal, rounded areas unequal in size and variable in number; deeply to shallowly impressed radial lines separate inflated surfaces and connect central depression with marginal indentations. Dimensions of holotype: Greater diameter 0.34 mm.; thickness 0.10 mm.

Type locality: Wheelock member of the Cook Mountain formation; Burleson County, Texas, near town of Bryan (see above).

Distribution: Middle Eocene (Claiborne group, Weches and Cook Mountain formations) of central Texas.

Remarks: Ten specimens have been examined. Five of these are from the type locality, the others from the Weches formation at Smithville, Texas (see above). The species is variable but seems to be a coherent entity.

ADDENDUM

A recent letter from H. K. Brooks (dated December 25, 1957) has given additional information on records of astacomorph crustaceans: Three species of supposed fresh-water crayfish have been recorded from the Cretaceous, in addition to the Mesozoic occurrence cited above, and two from the early Cenozoic. Brooks, however, questions the environmental interpretation for those forms (see also Brooks, 1957, p. 922, review of Packard, 1881).

Interpretation of the faunal components of an ancient estuary, and even of marine and non-marine sediments near a river mouth, is always debatable. Transportation of fresh-water organisms into marine beds is common, but the entry of salt-water animals into fresh water is perhaps less familiar to paleontologists. Numerous marine fish invade rivers, and sharks and saw-fish frequently find their way into mountain lakes by way of tributary streams. Among the crustaceans, we know of an example in the Chira River of northwestern Peru, where edible marine crabs (probably *Callinectes*) found their way a number of miles upstream and were caught at the inlet to the processing plant of the completely fresh water-supply for a large settlement.

Because of these two sources of mixture of marine and fresh-water faunal elements in sediments—biocoenotic invasion and thanatocoenotic transport—we agree with Brooks that strong evidence is required to establish a fresh-water origin for fossil crayfish. Huxley's idea of a Cenozoic migration of astacids and parastacids into fresh water, cited above, still seems to be the more tenable hypothesis.

We are further indebted to Dr. Brooks for pointing out the latest classification of both fossil and Recent astacomorphs (Roger, 1953), which differs somewhat from the zoological arrangement that we have used. Of these groups, only the Herpochelida is known to include forms secreting gastroliths.

Order Decapoda Latreille, 1802
- Suborder Trichelida Beurlen and Glaessner, 1931
  - Division Proherpochelida Beurlen and Glaessner (= Paranephropsidea Beurlen, 1929)
    - Family Erymaidae van Straelen, 1924 — Triassic to Cretaceous
    - Family Stenochiridae Beurlen and Glaessner, 1931 — Triassic to Jurassic
  - Division Herpochelida Beurlen and Glaessner, 1931 (= Nephropsidea Alcock)
    - Family Nephropsidae Stebbing, 1893 — Jurassic to Recent
    - Family Potamobiidae Huxley, 1878 (= Astacidae) — Cretaceous to early Cenozoic; Recent (fresh water)
    - Family Parastacidae Huxley, 1878 — Pleistocene to Recent (fresh water)

REFERENCES

Brooks, H. K.
1957 – *Chelicerata, Trilobitomorpha, Crustacea (exclusive of Ostracoda) and Myriopoda.* In: Ladd, H. S. (editor), *Treatise on marine ecology and paleoecology.* Geol. Soc. Amer., Mem. 67, vol. 2 (Paleoecology), pp. 895–929.

Frizzell, D. L., and Exline, H.
1956 – *Monograph of fossil holothurian sclerites.* Missouri, Univ., School Mines and Met., Bull., Tech. Ser., no. 89 (1955), pp. 1–204, pls. 1–11, text-figs. 1–21, 1 table.
1958 – *Fish ossiculiths: Unrecognized microfossils.* Micropaleontology, vol. 4, no. 3, pp. 281–285, text-figs. 1–7.

Hemming, F.
1957 – *Proposed addition to the "Regles" of provisions recognizing and regulating the nomenclature of "parataxa."* Jour. Pal., vol. 31, no. 6, pp. 1180–1183.

Herrick, F. H.
1911 – *Natural history of the American lobster.* [U. S.] Bur. Fisheries, Bull., no. 29 (1909), pp. 149–408, pls. 29–47, text-figs. 1–42, 15 tables.

Howell, J. V. (coordinating chairman)
1957 – *Glossary of geology and related sciences.* Amer Geol. Inst., Publ. no. 501, pp. 1–325.

Huxley, T. H.
1895 – *An introduction to the study of zoology, illustrated by the crayfish.* New York: D. Appleton & Co., International Scientific Series, vol. 28 (1880?), 371 pp., 82 text-figs. (Citation of this work varies, and the date usually is given as 1880. The publishers cite the title, in a flyleaf advertisement, as "The crayfish: An introduction to the study of zoology." Authors usually give it simply as "The crayfish.")

KOZLOWSKI, R.
1956 – *Sur quelques appareils masticateurs des annélides polychètes ordoviciens.* Acta Pal. Polonica, vol. 1, no. 3, pp. 165–210, text-figs. 1–20.

MOORE, R. C., SYLVESTER-BRADLEY, P. C., AND OTHERS
1957 – *Case No. 1: Suggested new article: Proposed recognition of the category "parataxon."* Bull. Zool. Nomencl., vol. 15, pt. 1/4, pp. 5–120.

MÜLLER, K. J.
1956 – *Taxonomy, nomenclature, orientation, and stratigraphic evaluation of conodonts.* Jour. Pal., vol. 30, no. 6, pp. 1324–1340, pl. 145.

RENICK, B. C., AND STENZEL, H. B.
1931 – *The lower Claiborne on the Brazos River, Texas.* Texas, Univ., Bull., no. 3101, pp. 73–108, text-figs. 9–11.

ROGER, J.
1953 – *Sous-classe des Malacostracés.* In: PIVETEAU, J., *Traité de Paléontologie.* Paris: Masson et Cie, vol. 3, pp. 309–378, pls. 1–11.

SAKAKURA, K.
1939 – *On a Mesozoic crayfish, Astacus licenti van Strälen, from Jehol, Manchuria.* Scientific Expedition to Manchoukuo, First Rept., sec. 2, pt. 2, 5 pp. (Japanese with English summary) (not seen; data from BROOKS, 1957, p. 924).

STENZEL, H. B.
1935 – *A new formation in the Claiborne group.* Texas, Univ., Bull., no. 3501, pp. 267–279, text-figs. 34–35.

STENZEL, H. B., KRAUSE, E. K., AND TWINING, J. T.
1957 – *Pelecypoda from the type locality of the Stone City beds (Middle Eocene) of Texas.* Texas, Univ. [Bur. Econ. Geol.], Publ., no. 5704, pp. 1–237, pls. 1–22, text-figs. 1–31, tables 1–4.

STORER, T. I.
1943 – *General zoology.* New York and London: McGraw-Hill, pp. 1–798, 551 text-figs., 5 pls.

ABSTRACT: *The term* ossiculith *is proposed for minute (0.05–0.50 mm.), planoconvex, ellipsoidal or irregular calcareous particles, often teratological, occurring sporadically in the auditory labyrinth of Recent fishes and extremely rarely identifiable as microfossils (Claiborne Eocene of Texas). Gastroliths of larval crayfish are similar in size and shape to planoconvex examples, but are distinguished by their calcareophosphatic composition, very fine lamination, and excavated channel.*

Fish ossiculiths: Unrecognized microfossils

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INTRODUCTION

Certain tiny and extremely rare microfossils of the Texas Middle Eocene have puzzled the senior author for a number of years. Until very recently, they were confused with superficially similar larval crustacean gastroliths occurring in association with them (Frizzell and Exline, 1958). These problematica, however, can now be identified positively with objects found in the auditory labyrinth of Recent fishes.

We are proposing the term *ossiculith* for these minute structures, compounded from "otolith" and "ossicle." The latter has been too widely used throughout the Animal Kingdom, and would not suitably distinguish the accessory ear stones. Such a term as "micro-otolith," although of associative value, might lead to confusion with smaller specimens of the true otoliths of fishes (sagitta, asteriscus, and lapillus).

The ossiculiths of Recent fishes apparently have not been described or noted, so we are recording more extensive notes than their paleontological value would otherwise justify. We are also including a brief description of the otoconia of elasmobranchs, as their structures are likely to be unknown to the paleontologist and because they have been reported in some of the higher fishes. In micropaleontology, recognition of ossiculiths has little importance except to insure that they are not confused with other microfossil groups, and to satisfy the systematist's basic urge to catalogue even the scraps and fragments in his collections. Ossiculiths are inconsistent in shape, and are not susceptible to any kind of nomenclature.

*Mrs. Don L. Frizzell

In dealing with Recent fishes, we are following the classification of Berg (1940). Identifications have been made from various references (not cited here), and we have made no attempt to bring generic and specific names up to date.

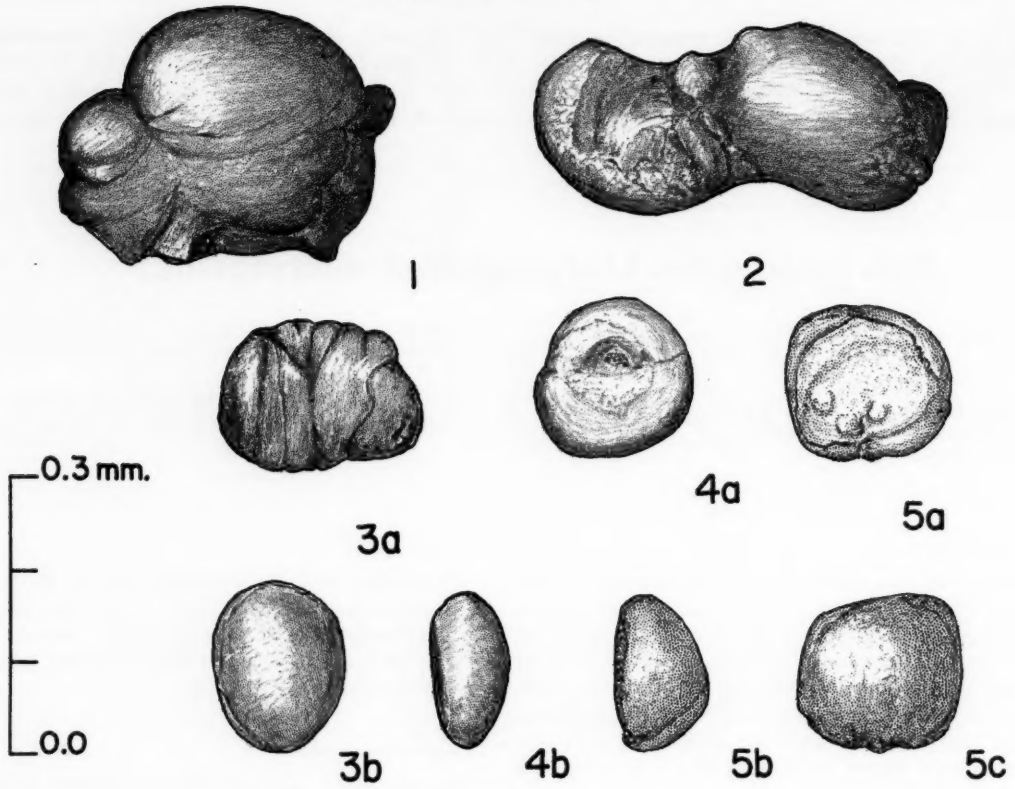
ACKNOWLEDGMENTS

In this study, we have been especially indebted to Dr. Kelshaw Bonham, Applied Fisheries, University of Washington, Seattle, for a specimen of *Squalus acanthias*, and to Mr. W. I. Follett, Curator of Fishes, California Academy of Sciences, San Francisco, for some essential references. Other assistance has been noted elshewhere (Frizzell and Exline, 1958).

OSSICULITHS OF RECENT FISHES

Ossiculiths have been found in the auditory labyrinth of seven species of teleostomous fishes belonging to two orders. No extensive search for these objects has been involved, but those encountered in extracting otoliths for other studies serve to establish their presence in a variety of marine and freshwater fishes.

Ossiculiths are calcareous, minute (ca. 0.05 to 0.50 mm. in greatest dimension), planoconvex, ellipsoidal, or irregular in shape, but varying widely in size and form. Usually developed within the sacculus, adjacent to the external side of the sagitta, they may be formed within the lagena, as shown in particular by an asteriscus with ossiculiths fused to its external surface. The origin of the smaller ellipsoidal ossicles is obscure, but the larger ossiculiths



TEXT-FIGURES 1–5

Recent ossiculiths: 1–4, rainbow trout *(Salmo gairdnerii* Richardson); 5a–c, sculpin *("Cottus ictalops* (Rafinesque)").

evidently are pinched-off ornamental nodes of the outer side of the sagitta.

Planoconvex specimens (text-figs. 4a–b, 5a–c) superficially resemble the gastroliths of larval crayfish in size and shape. The flattened side has an incised line that is analogous to the channel of the gastrolith, and the central portion of the ossiculith also is differentiated from the peripheral margin. The gastrolith, however, is calcareophosphatic rather than calcareous, and its inner structure of very fine lamellae is characteristic. The resemblance between the two structures is due to similarity of the secreting mechanism (Frizzell and Exline, 1958).

Slightly more than half the occurrences of ossiculiths were in association with deformed otoliths, indicating a pathological or at least teratological condition in the labyrinth. In the remainder, however, the ear stones seemed to be completely normal. In a single species examined, the sciaenid *Micropogon undulatus* (Linné), the association of very numerous ossiculiths with normal but highly modified sagittae suggests a characteristic occurrence of those structures.

The following notes are intended to summarize the examples of ossiculiths found. For brevity, descriptions are given in telegraphic style.

Class TELEOSTOMI

Subclass ACTINOPTERYGII

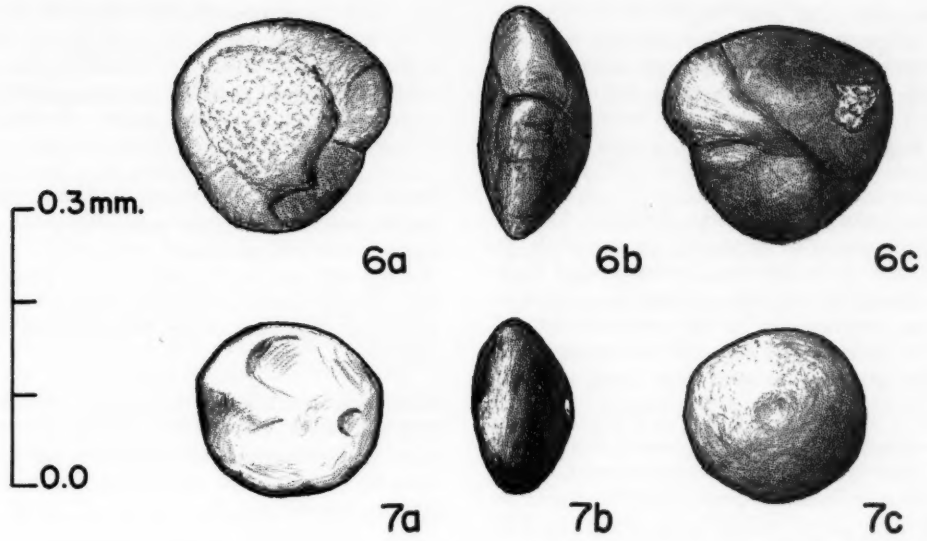
Order CLUPEIFORMES

Suborder SALMONOIDEI

Family SALMONIDAE

Salmo gairdnerii Richardson
(rainbow trout)
Text-figures 1–4

Fresh water; Montauk Park, Missouri. Ossiculiths are rare and sporadic, one fish showing seven in the left sacculus and none in the right. The left sagitta



TEXT-FIGURES 6–7
Middle Eocene ossiculiths from Smithville, Texas.

is slightly atypical, the accompanying asteriscus markedly deformed. All otoliths of the right side are normal.

Ossiculiths translucent, varying markedly in size (0.10 to 0.43 mm. in greatest dimension) and shape, characterized by rounded surfaces; three specimens similar to Eocene examples, but differing widely among themselves, remainder of bizarre form.

Order PERCIFORMES

Suborder PERCOIDEI

Superfamily PERCOIDAE

Family CENTRARCHIDAE

Lepomis cyanellus Rafinesque
(green sunfish)

Fresh water; Montauk Park, Missouri. One fish contained an ossiculith in the left sacculus, the accompanying sagitta being undeformed. Ossiculiths definitely were absent from the right side.

Ossiculith translucent, moderately large (maximum dimension, 0.39 mm.), irregular, unusual in showing an angular bifurcation and in having uncharacteristic straight lineations on the surface; unlike any of the figured specimens.

Micropterus sp. cf. **M. punctulatus** (Rafinesque)
(Kentucky(?) bass)

Fresh water; Montauk Park, Missouri. Three bass were carefully examined. One contained normal sets of otoliths without auxiliary ossicles, the others showing ossiculiths associated with more or less deformed ear stones.

(1) *Left sacculus:* Five tiny, irregularly ellipsoidal ossicles (0.05 to 0.09 mm. long); three larger ossiculiths (0.20 to 0.25 mm. in greater diameter), one markedly irregular and the others irregularly rounded; excisura and anterior ventral margin of sagitta deformed, marked by excrescences of glassy-clear material. *Right lagena:* Seven minute ossiculiths (0.06 to 0.09 mm. long), identical with those of left sacculus.

(2) *Left labyrinth* not extracted, but a single ossiculith adhered to exterior of sagitta as it was removed. Ossiculith subspherical with flattened side, 0.14 mm. in maximum dimension, somewhat resembling Eocene microfossils; accompanying sagitta normal. *Right sacculus* with deformed sagitta and four ossiculiths; rostral projection of sagitta apparently broken and recemented with clear material. One ossiculith resembling fossil forms in flat top and rounded bottom; two others tiny (0.10 and 0.14 mm. long), irregularly ellipsoidal and pyriform; fourth composite, of fused rounded ossicles, maximum dimen-

sion of ossiculith 0.38 mm. *Right asteriscus* nearly normal in shape and glassy-clearness, but has one tiny spherical ossicle and several larger, translucent, ossiculith-like structures fused to exterior.

Pomoxis sparoides (Lacépède)
(black crappie)

Fresh water; Lake of the Ozarks, Missouri. Of five fish examined, only one produced an ossiculith. It occurred in the right sacculus, accompanied by a slightly abnormal sagitta with unusual development of projecting irregularities on the posterior ventral margin. The left sacculus, although unaccompanied by ossicular growths, showed the same type of structure.

Ossiculith minute (length 0.34 mm.; maximum diameter 0.20 mm.), irregularly conical, with numerous broadly rounded projections ranging from tiny to relatively large; unlike fossil specimens, but similar to some of those from trout.

Family SCIAENIDAE

Micropogon undulatus (Linné)
(croaker)

Marine; Corpus Christi, Texas. One croaker was examined, showing an abundance of ossiculiths associated with the normal (although considerably modified) sagittae. They vary greatly in size and shape, showing no consistency of form, and are largely made up of fused subspherical ossicles. Some are clear, others chalky. The extremely numerous ossiculiths apparently are correlated in some way with the excavations in the sagitta typical for *Micropogon undulatus*, and they may be characteristic for the species.

Suborder TRICHIUROIDEI

Family TRICHIURIDAE

Trichiurus lepturus Linné
(cutlass fish)

Marine; Corpus Christi, Texas. Two poorly preserved heads were examined. One showed no ossiculiths, but the other contained several within the right sacculus. They are irregular to spherical, the largest (0.31 mm. in greatest dimension) being an aggregate of many very minute spherical ossicles; all are somewhat chalky. The ossiculiths unquestionably are pathological, as the right asteriscus had moved into the sacculus and had become fused with the outer side of the sagitta, a completely abnormal condition.

Suborder COTTOIDEI

Family COTTIDAE

"Cottus ictalops (Rafinesque)"
(sculpin)
Text-figure 5a–c

Fresh water; Current River at Akers, Missouri. A single ossiculith was extracted from the right sacculus of one fish, associated with normal otoliths, but the left side was not examined in enough detail to establish the possibility of the presence of additional examples. A second sculpin definitely did not contain ossiculiths.

Ossiculith nearly opaque, minute (greatest dimension 0.20 mm.), subcircular, planoconvex; flattened side with submarginal depression and very low arched center; very similar in basic features to Eocene microfossils.

OTOCONIA OF THE DOGFISH

Otoliths and otoconia (ear dust) are associated in some primitive true fish (the sturgeon, *Acipenser:* Class Teleostomi, Subclass Actinopterygii, Order Acipenseriformes, according to Shepherd, 1910, 1914, 1915). Moreover, the aberrant actinopterygian genus *Mola* (marine sunfish: Order Tetrodontiformes) also has otoconia, although lacking otoliths (Shepherd, 1914). An investigation of unquestionable otoconia was therefore required, in order to check the possibility that ossiculiths might be identical with those deposits. The auditory labyrinth of a dogfish (*Squalus acanthias:* Class Elasmobranchii) was extracted for this purpose.

The statoliths of the dogfish consist of sparse sand grains and extremely abundant otoconia. The latter, secreted within the labyrinth, are clear calcite crystals, varying in size (at least from 0.04 to 0.38 mm.), with well developed faces. Otoconia differ very markedly from the ossiculiths of Recent fishes in their transparency and angularity, and they do not resemble the Eocene microfossils.

FOSSIL OSSICULITHS

Three specimens of recognizable fish ossiculiths have been studied from Middle Eocene beds in Bastrop County, Texas, where they were associated with crustacean gastroliths of comparable size. Their close resemblance to the planoconvex examples of ossiculiths from Recent trout, Kentucky(?) bass, and sculpin (text-figs. 1–5) serves to establish their identity beyond question.

Two specimens are virtually identical. They are calcareous, minute (one is 0.23 mm. in greater diameter; the other, shown in text-figure 6a–c, is 0.24 mm. in greater diameter and 0.11 mm. in thickness), relatively thin, subtriangular; periphery smooth or slightly indented; top flat or slightly convex, central part gently arched upward, with a lightly incised line; bottom nearly smooth, rounded from periphery to center, with shallow radial lines.

The third specimen (text-fig. 7a–c) differs in some details. It is minute (0.20 mm. in greater diameter), relatively thick (0.11 mm.), subcircular; periphery smooth; top slightly convex, not differentiated by an incised line into central and peripheral parts; bottom smooth, rounded from periphery to center, with small and shallow central depression.

Fish ossiculiths are probably much more abundant microfossils than these meager records would suggest, and they may be frequent in the minute calcareous debris of many samples, but in general they cannot be recognized. The distinguishable planoconvex type is a minor occurrence among the ossiculiths of Recent fishes, and no criteria have been found for the recognition of other variants. Because of the inconsistency in the shape of fish ossiculiths, no valid system of nomenclature could be established for these fossils.

DESCRIPTION OF FOSSIL LOCALITY

Middle Eocene, Claiborne group, Weches formation, Viesca member; Smithville, Bastrop County, Texas; south bank of the Colorado River, about 0.1 mile west of the highway bridge [now a short distance *east* of the present bridge on Texas Highway no. 71]; a highly glauconitic shale near the base of the exposure, about two feet stratigraphically below an indurated stratum with abundant pelecypods; collected by Helen J. Plummer, D. L. Frizzell, and H. E. Frizzell, March 3, 1946 (see Frizzell and Exline, 1958, for additional details).

REFERENCES

BERG, L. S.
1940 – *Classification of fishes, both Recent and fossil.* Acad. Sci. U.R.S.S., Inst. Zool., Trav., vol. 5, no. 2, pp. 87–517, text-figs. 1–190 (complete Russian and English text; lithoprint edition, Ann Arbor, Michigan: J. W. Edwards, 1947).

FRIZZELL, D. L., AND EXLINE, H.
1958 – *Crustacean gastroliths from the Claiborne Eocene of Texas.* Micropaleontology, vol. 4, no. 3, pp. 273–280, text-figs. 1–10.

SHEPHERD, C. E.
1910 – *Comparisons of otoliths found in fishes.* Zoologist, ser. 4, vol. 14, pp. 292–298, 2 pls.
1914 – *On the location of the sacculus and its contained otoliths in fishes.* Zoologist, ser. 4, vol. 18, pp. 103–109, 131–146, 3 text-figs.
1915 – *On the location of the sacculus and its contained otoliths in fishes (continued).* Zoologist, ser. 4, vol. 19, pp. 25–34, text-figs. 1–7.

ABSTRACT: *A study of the foraminifera of the Santa Cruz Basin has revealed relationships between the living and dead populations. Two wide depth zones are recognized, into which both living and non-living individuals can be grouped. A slight depth zonation of living forms is present below sill depth. Distributional trends exhibited above sill level are: (1) A slight decrease in the number of living genera and species with depth, and (2) a decrease in the concentration of tests with depth. Below sill depth the following conditions exist: (1) A greatly reduced number of living genera and species; (2) a relatively uniform test concentration; and (3) over 50 per cent reduction in the concentration of planktonic tests. Recent distributional patterns within the basin are complicated by the presence of Miocene, Pliocene, and Pleistocene fossils. Two new foraminiferal species are described.*

Ecology of foraminifera of the Santa Cruz Basin, California

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INTRODUCTION

General

Paleontology, from its inception as a subject of speculation to its acceptance into the science of correlation, has become an increasingly complicated tool. Intensive investigations have revealed the facts that lateral gradations in faunas exist, and that completely different faunas may be of the same age, and may merely express varying environmental conditions. It has thus become necessary to determine the habitats of faunas living today as an indication of the past environments of the same or similar fossil forms. In this manner, the paleoecology of fossil sediments, as well as the time equivalence of different facies in the sedimentary record, may be established.

Throughout the geologic history of California, sedimentation has taken place in basinal environments. The purpose of this paper is to contribute to the interpretation of foraminiferal distributions in former basins through study of the living and dead populations of foraminifera in one of the present offshore basins. The Santa Cruz Basin was selected for this study because of the great difference in depth between the sill, or lowest point on the rim, and the basin bottom, offering a maximum area of closure in which to study the ecological effects of a basinal environment.

Area

The Santa Cruz Basin is located southeast of Santa Cruz Island, Santa Barbara County, California, centering at lat. 33°42′ N. and long. 119°33′ W. (text-fig. 1). It is a large basin, attaining a depth of 1070 fathoms and having an area of 1078 square miles and a water capacity of 533 cubic miles. The elongation and trend of the basin are northwest-southeast, in common with the orientation of the many basin and ridge structures making up the California borderland.

Direct connection with the San Nicolas Basin to the southeast is by means of the sill, which is submerged at a depth of 592 fathoms. On all remaining sides, the basin is bounded either by submerged ridges or by islands and insular shelves. Seaward, a portion of the Santa Rosa–Cortes Ridge separates the Santa Cruz Basin from the edge of the continental shelf and from the open sea. Toward the mainland, another ridge separates the basin from the Santa Monica Basin. From these two main ridges, islands rise above the surface of the sea. Santa Cruz Island, the largest of the surrounding islands, lies at the northern boundary of the basin, where the two ridges coalesce. At the opposite or sill end of the basin, San Nicolas Island rises from the seaward ridge, and Santa Barbara Island emerges on the landward side of the sill.

Methods

During March and May of 1955, samples of bottom material were obtained by means of a Hayward orange-peel grab. This was considered the best method of collecting a large amount of relatively undisturbed surface material, which is important in the study of living populations. Using an orange-peel grab with a capacity of two cubic feet, it was possible to recover approximately two square feet of the bottom surface. The upper inch of material trapped in the sampler was carefully spooned off and placed in isopropyl alcohol in order to preserve any living tissues that might be present. Although some peripheral mixing of material is known to occur in this type of sampler, it was felt that by taking only the material near the center of the collected field, a representative portion of undisturbed surface area would be obtained.

Rose bengale, an organic stain, was later added to the preserved samples (Walton, 1952, p. 60). This stain served to color the protoplasm and tests of living individuals a reddish color, whereas empty tests retained their natural colors.

After a period of drying, the samples were weighed to the nearest centigram and were then washed through a 250–mesh screen with a screen opening of .062 mm. The material remaining on the screen was again dried, after which separation of foraminifera from the heavier sediment was carried out by means of carbon tetrachloride flotation.

The relative abundances of the various species of foraminifera were obtained by counting at least 300 benthonic foraminifera in each sample. When foraminifera were highly concentrated in a sample, it was necessary to split the sample, using a microsplitter, down to a minimum of 1/32 of the original concentrate. To determine the abundance of living individuals, the entire concentrate was examined.

Previous investigations

Former foraminiferal investigations in the general area under consideration fall into two categories, descriptive works and ecologic studies. The descriptive works were extremely useful to the present author in the identification of species of foraminifera from the basin, and are listed in the bibliography.

Ecologic studies began in this area when Natland (1933) collected Recent foraminifera along a traverse across the San Pedro Basin. Five faunal zones based upon temperature and depth were established in that work. The zones extended from the intertidal area down to a depth of 1390 fathoms (8340 feet).

Butcher (1951) and Phleger (1951) investigated the depth ranges of Recent foraminifera in the San Diego area. Phleger recognized displaced shallow-water faunas in deep-water sands.

A study of the foraminifera in cores taken from eleven offshore basins was made by Crouch (1952). No zonation of foraminifera was noted below the sill levels of the basins. As the temperatures below sill depth are nearly isothermal, it was felt that temperature was probably the factor controlling distribution. The Santa Cruz Basin was included in Crouch's study.

In a study of three profiles off the California coast, Bandy (1953) noted north-south variation as well as bathymetric change. Temperature was considered the most probable agent responsible for both vertical and horizontal zonation.

The most recent ecologic work, and the only one thus far dealing with living populations, is that of Walton (1955). Although Walton's work was done off Baja California, many of the species found and many of the conclusions reached are in accord with those of the present paper. Walton concluded that types of substratum, food supplies, and feeding habits, as well as depth and temperature variations, may serve to limit the distribution of foraminifera in certain environments.

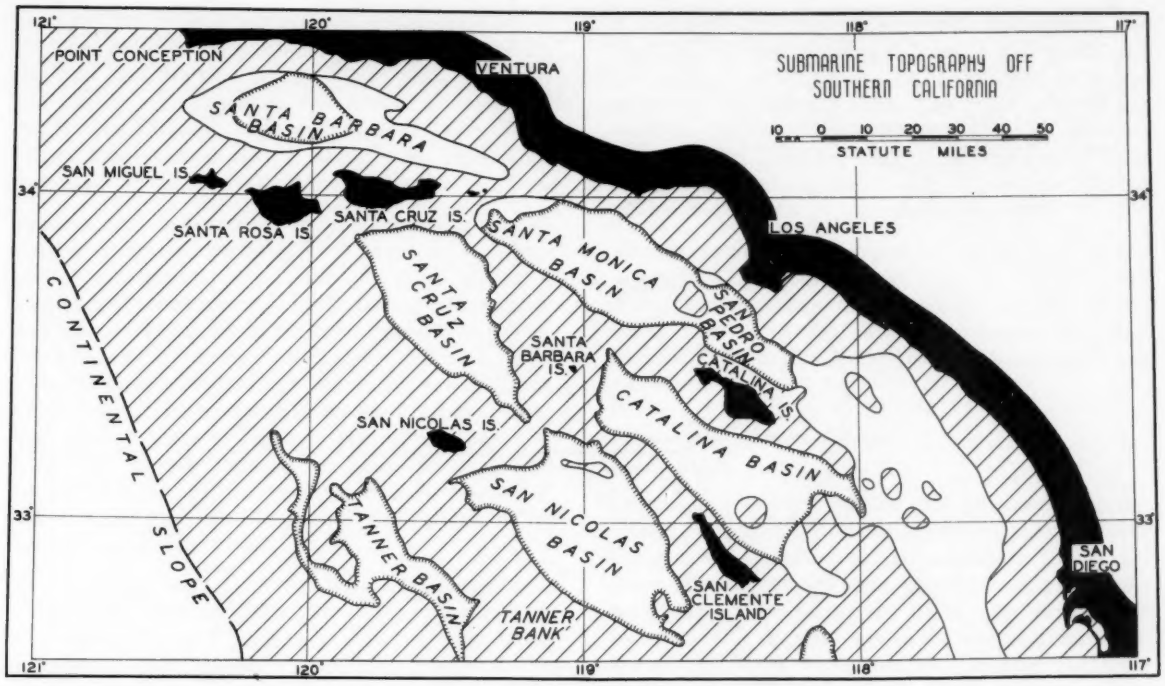
Acknowledgments

This project, which was originally carried out as the basis for a master's thesis, was financed through the aid of Captain Allan Hancock and the Allan Hancock Foundation of the University of Southern California. This organization also made available the research vessel *Velero IV* for the collection of material. The writer is indebted to Emil Zalesny for his work in collecting samples; to Drs. K. O. Emery and W. H. Easton for criticism of the manuscript; and to Dr. Orville Bandy for suggesting the topic and for his immeasurable assistance in both the laboratory and the written phases of this work.

GEOLOGIC AND OCEANOGRAPHIC CONDITIONS

Submarine topography and structure

Structurally, the Santa Cruz Basin is a graben (Shepard and Emery, 1941, p. 47, text-fig. 18). Fault scarps are well developed on the north, east, and west sides of the basin, forming steep, straight slopes. The slopes, generally inclining 7° (a maximum of 15° to the west of Santa Barbara Island), rise from a relatively flat basin floor.



TEXT-FIGURE 1

MAP SHOWING LOCATION OF SANTA CRUZ BASIN

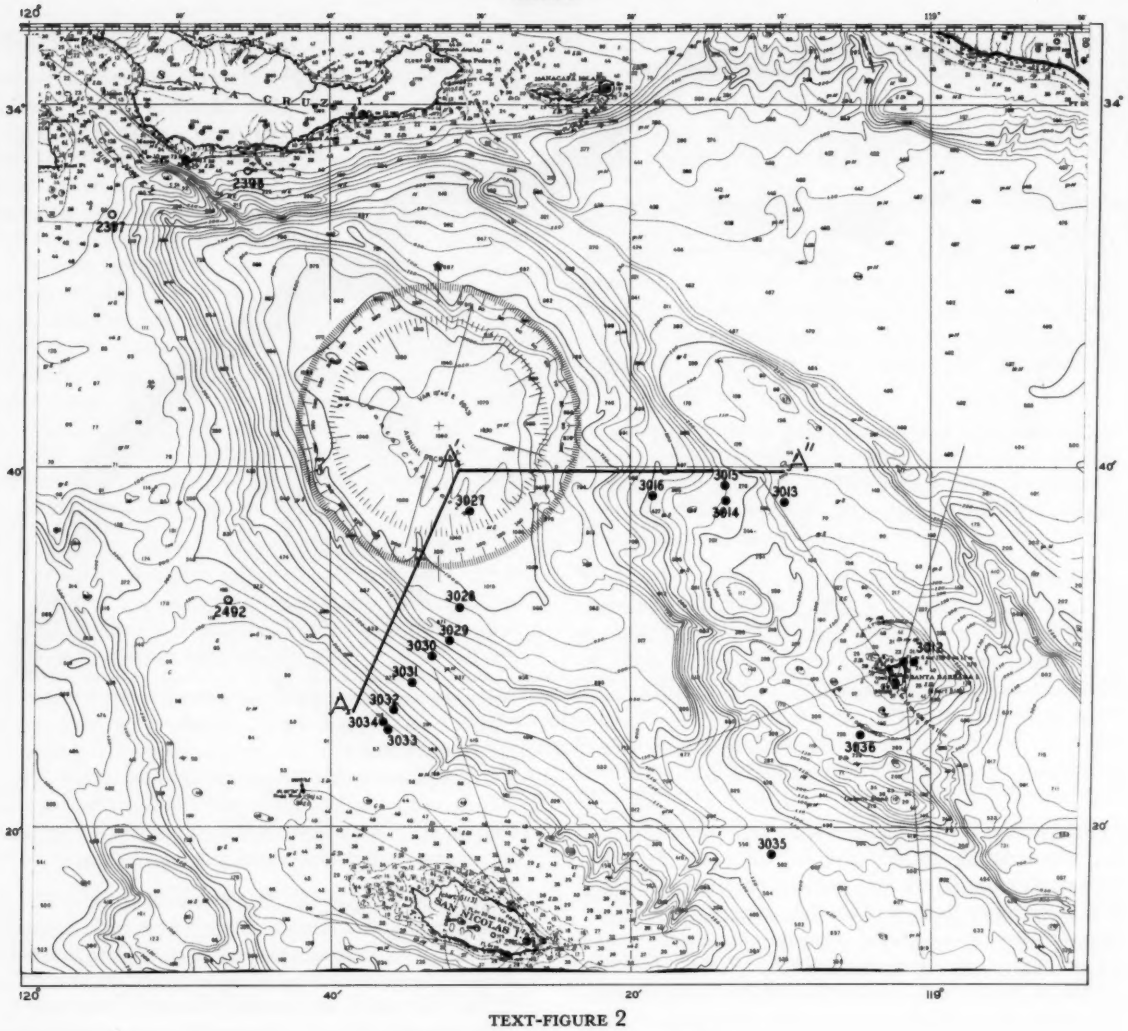
As the basin is the downthrown block between faults, the surrounding banks and islands are elevated masses. The banks are long, narrower than the basin, and almost flat-topped. Grooves formed by erosion along planes of structural weakness lie transversely across the banks, forming saddles. One of these saddles is present on the portion of the Santa Rosa–Cortes Ridge bordering the basin, and one on the ridge bounding the landward side of the basin. The lowest groove of this type, forming what is known as the sill of the basin, is located between San Nicolas and Santa Barbara Islands.

The structure of the neighboring islands is complex, exhibiting intricate faulting and folding. The main structural feature of Santa Cruz Island is a faulted anticline trending parallel to the longitudinal axis of the island (Bremner, 1932, p. 28). This island affords the maximum relief of the area, rising over 2400 feet above sea level or 9000 feet above the basin floor. Santa Barbara Island is cut into blocks by two intersecting fault systems, one trending northeast and the other in a northwest direction (Grady, MS.). A northwest-trending anticline, modified by folding, faulting, and the development of marine terraces, forms San Nicolas Island (Norris, 1951, p. 2). The islands are surrounded by insular shelves showing evidences of former terraces.

Heading in the gap between Santa Rosa and Santa Cruz Islands, the Santa Cruz submarine canyon extends for 13 miles down the basin rim in a southeasterly direction. The canyon cuts as much as 900 feet below the surrounding slope, and terminates in 650 fathoms of water. Below the canyon terminus, which corresponds closely to the sill depth of the Santa Cruz Basin, typically steep (8^0) basin slopes continue. In addition to the one major canyon, several minor submarine canyons enter the basin from the direction of San Nicolas Island.

Sediments

The sedimentary framework upon which block faulting took place is composed almost entirely of Miocene strata, with limited exposures of Eocene rocks. In a study of the Santa Rosa–Cortes Ridge, Uchupi (MS.) found Saucesian, Relizian, and Mohnian shales in the area north of Begg Rock, and Relizian shales on the shelf of Santa Rosa Island. South of Begg Rock, Middle and Upper Eocene shales, sandstones, and siltstones were encountered. An upper Mohnian shale outcrop was sampled at



TEXT-FIGURE 2

INDEX MAP OF SAMPLE LOCATIONS

Solid circles indicate preserved samples; unpreserved samples are shown by open circles.

200 fathoms on the southwest rim of the basin in gathering material for this report. On the opposite side of the basin, Middle and Upper Miocene shales were found on the shelf of Santa Barbara Island (Grady, MS.).

Surrounding islands exhibit sediments ranging in age from Paleocene to Pleistocene. The greatest variation in sediments is found on Santa Cruz Island, where a Jurassic(?) metamorphic basement is overlain by the Paleocene Martinez formation and the Eocene Domengine formation, both composed of shales, sandstones, and conglomerates; the Miocene Temblor and Monterey formations, consisting of sandstones, conglomerates, siliceous shales, limestones, cherts, and volcanics; and Pleistocene terrace deposits (Bremner, 1932). Miocene volcanics form the rugged topography of Santa Barbara Island. They are interrupted only by a single Miocene sedimentary bed (Grady, MS.). Here also the older strata are mantled by Pleistocene terrace deposits. On San Nicolas Island, Middle and Upper Eocene buff sandstones and shales are unconformably overlain by Pleistocene terrace material and Recent sand dunes. As exposed along the shore, the sediments attain a thickness of 2000 feet.

In the basin proper, indications of the presence of Pliocene material were found at the sill and on both the east and the west slopes. Pleistocene foraminiferal sands are present on the northern rim of the basin, and probably also extend over parts of the Santa Rosa–Cortes Ridge, along with Pleistocene gravels.

Present accumulation in the area consists of calcareous organic material and authigenic phosphorite and glauconite on the banks (Uchupi, MS.), and finer-grained material in the basin. Sedimentary analysis was not made in this investigation; however, inspection of collected material revealed rock cropping out from 90 to 500 fathoms on the eastern slope of the basin. The west side displayed gradation from fine sand at the rim through intermediate textures from 400 to 600 fathoms, to mud on the basin bottom. Emery and Rittenberg (1952, p. 738) found the average grain size near the lowest point in the basin to be 3.2 microns.

Using seismic reflection and refraction techniques, it has been calculated that the combined thickness of sediment in and beneath the Santa Cruz Basin is around 9000 feet (Raitt, 1949). This was the greatest thickness recorded by these methods inside the continental slope off southern California.

Oceanography

Surface currents, as computed from temperature-salinity measurements (Sverdrup and Fleming, 1941, p. 344), flow in a southeasterly direction outside the Santa Rosa–Cortes Ridge. On the shoreward side of the ridge, however, a large eddy is developed, with currents flowing to the north. The surface water of the Santa Cruz Basin represents a mixture of water upwelled because of the obstruction of deep-water movements by the ridge, and surface water transported from offshore.

Deeper basin waters emanate from the San Nicolas Basin, where, by flowing to the north, they enter the Santa Cruz Basin over the southern sill (Emery, 1954). Because of increasing density with depth of water, the densest water that can cross the sill is that near sill depth, and this water fills the basin from the level of entrance to the bottom.

Previous investigations of the properties of the basin water have largely been restricted to temperature and salinity measurements. Water temperature decreases from approximately 7.5° C. at 50 fathoms to 4.15° C. below the sill, below which it is nearly isothermal. Above 50 fathoms, seasonal fluctuations in temperature are evident, whereas below the sill, a constant temperature prevails throughout the year. Chlorinity increases from 18.43 parts per thousand at the surface to 19.11 parts per thousand below the sill (Emery, 1954). Oxygen content of the water below sill depth averages 0.8 ml./L. (Rittenberg, Emery, and Orr, 1955, p. 25, text-fig. 2). This figure is high as compared with the oxygen content of the deep waters of surrounding basins.

Constant renewal of basin water takes place as the upper, less dense layers mix with the waters at sill level. The resulting decrease in the density of the water near sill depth allows new water from San Nicolas Basin to displace that which has become less dense.

DISTRIBUTION OF FORAMINIFERA

Sample locations

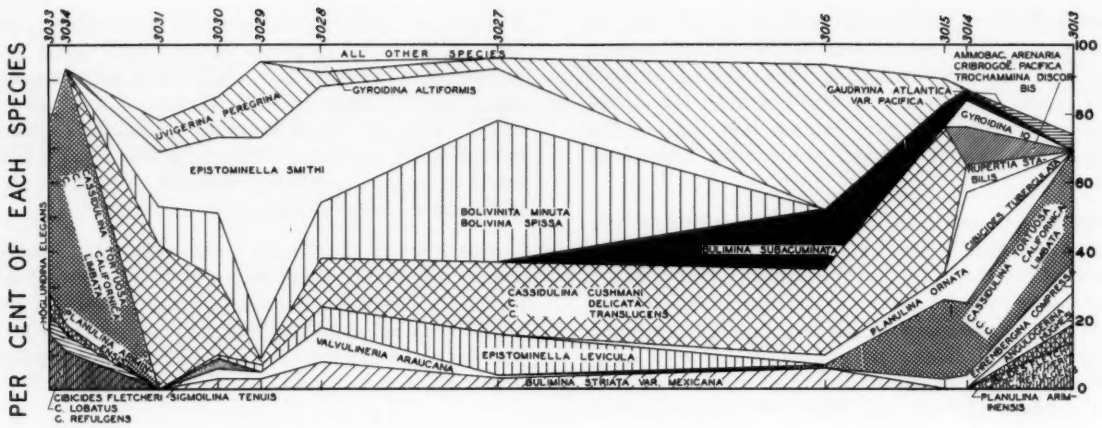
Fourteen preserved samples were obtained from the Santa Cruz Basin, and an additional sample from the northeast landing at Santa Barbara Island. Of these, twelve samples were located on a southwest-northeast profile across the basin, one sample was located at the sill, and one to the northeast between the sill and Santa Barbara Island (text-fig. 2). Three additional samples from the north and west rims of the basin were obtained from the collections of the Allan Hancock Foundation. The latter were not preserved. The latitude and longitude and the depth of each sample is given in Table 1.

TABLE 1

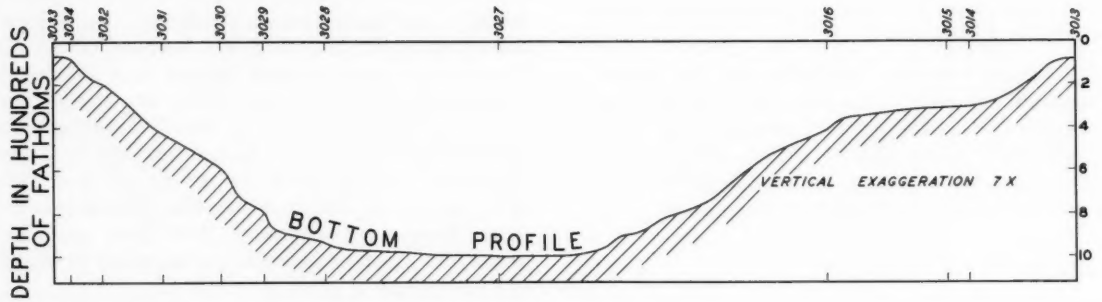
SAMPLE LOCATIONS

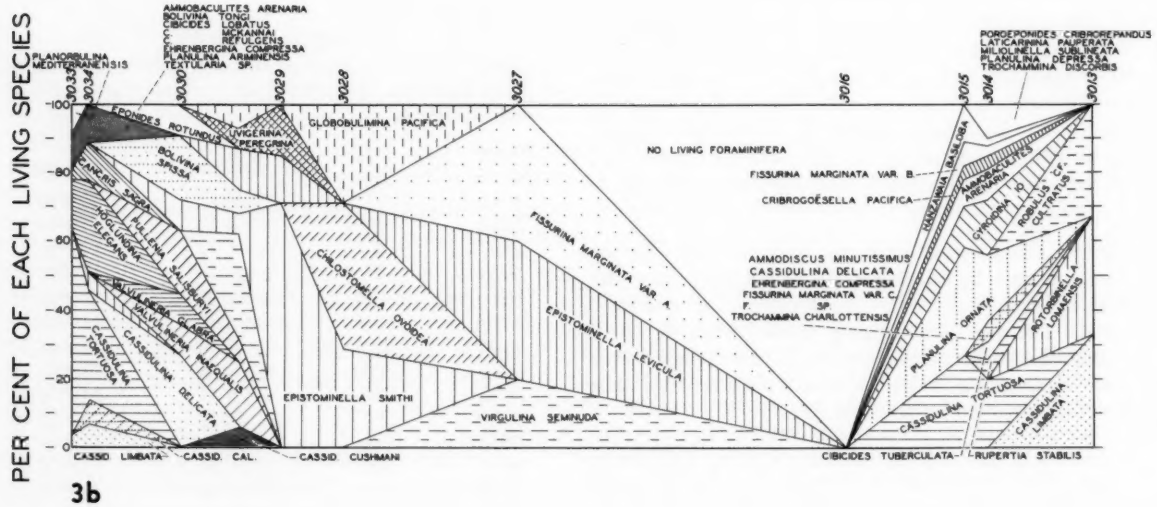
Sample numbers listed in this section are those of the Allan Hancock Foundation of the University of Southern California.

Sample number	*Depth (fms.)*	*Latitude*	*Longitude*
3012	10	33°28′57″	119°10′20″
2398	50	33°56′18″	119°45′38″
2397	67	33°54′22″	119°54′33″
3033	75	33°25′45″	119°37′00″
3034	80	33°25′50″	119°36′41″
3013	90	33°38′39″	119°09′41″
2492	153	33°32′50″	119°47′30″
3032	200	33°26′38″	119°35′58″
3036	200	33°25′31″	119°04′52″
3014	297	33°38′52″	119°13′40″
3015	312	33°39′00″	119°13′56″
3031	400	33°28′04″	119°34′41″
3016	510	33°38′46″	119°18′37″
3035	562	33°18′28″	119°10′16″
3030	600	33°29′33″	119°33′07″
3029	800	33°30′25″	119°31′57″
3028	950	33°32′15″	119°31′22″
3027	1020	33°37′38″	119°30′28″



3a





3b

TEXT-FIGURE 3

FREQUENCY DISTRIBUTION OF FORAMINIFERA

a, frequency distribution of total population; b, frequency distribution of living foraminifera.

Benthonic foraminifera

Frequency distributions of living and dead foraminifera plotted over the basin profile A–A′–A″ show a correlation of foraminiferal assemblages with depth (text-fig. 3a). Comparison of the total populations with the distribution of living foraminifera (text-fig. 3b) makes it possible to separate the actual inhabitants of the various depths from fossil or displaced forms.

Considering first the west side of the basin, it can be observed that at depths of less than 200 fathoms, all of the species represented on the total population chart, with the exception of *Cibicides fletcheri*, were found living at the place of test accumulation. In addition, a number of species composing insignificant proportions of the total population were found living in these depths. Among these are: *Ammobaculites arenaria*, *Bolivina tongi*, *Cancris sagrai*, *Ehrenbergina compressa*, *Planorbulina mediterranensis*, *Robulus cushmani*, *Rotorbinella lomaensis*, and *Textularia* sp.

Below 250 fathoms, the remainder of the species diagrammed on the total population chart have the following living ranges: *Cassidulina delicata* 250–500 fathoms (greatest abundance 400 fathoms); *Bolivina spissa* 250–700 fathoms (greatest abundance 400 fathoms); *Cassidulina cushmani* 500–700 fathoms (greatest abundance 600 fathoms); *Uvigerina peregrina* 500–900 fathoms (greatest abundance 800 fathoms); *Epistominella smithi* 250–1000 fathoms (greatest abundance 800 fathoms); and *Epistominella levicula* 500–1020 fathoms (greatest abundance 1200 fathoms). The living distributions of *Bolivina spissa*, *Cassidulina cushmani*, *Cassidulina delicata*, *Uvigerina peregrina*, and to a lesser extent *Epistominella smithi*, are at the upper limits of the test distributions, indicating displacement of tests down-slope after death. Only *Epistominella levicula*, being an inhabitant of the deepest part of the basin, has shown little, if any, displacement.

On the east side of the basin, no living foraminifera were found at 510 fathoms, probably because of the rocky character of the bottom and poor sampling conditions. Information concerning the distribution of living forms is thus available only down to 300 fathoms. Foraminifera of the east side are generally found living where their tests have accumulated. Forms diagrammed on the total distribution chart which were not found living are: *Angulogerina hughesi*, *Cibicides fletcheri*, *Cibicides refulgens*, *Gaudryina atlantica* var. *pacifica*, and *Planulina ariminensis*. The remainder of the species were well represented in the living population along with a large number of species which were not diagrammed because of their small representation in the total population.

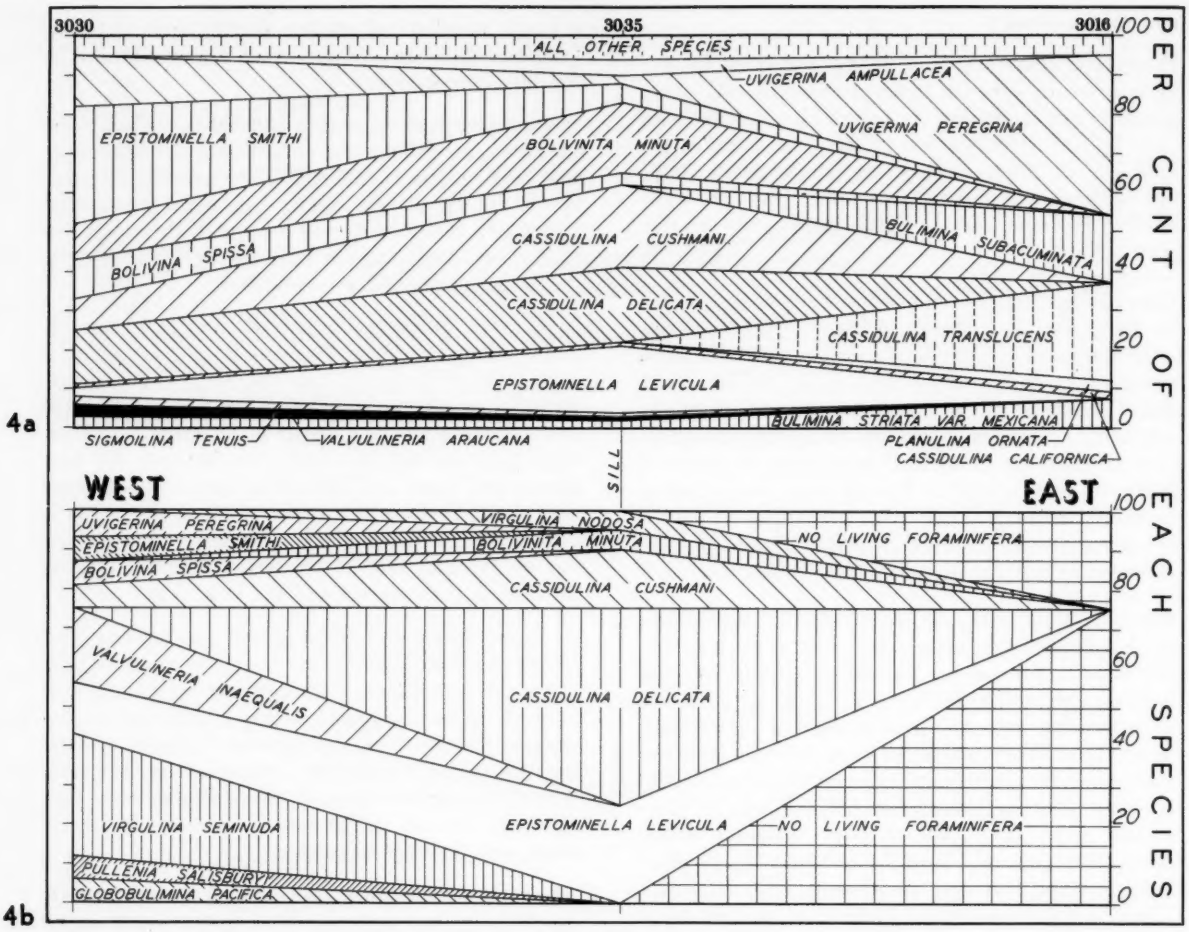
Faunal distributions within the basin could not be summarized without first considering the foraminiferal populations at sill level. The similarity of water properties below sill depth has been mentioned previously. Sill-level faunas represent, therefore, the shallowest living animals that can be influenced by the homogeneity of basin conditions.

A relationship exists between the species on the sill and at comparable depths on both the east and the west sides of the basin (text-fig. 4a). Three forms, *Bulimina striata* var. *mexicana*, *Cassidulina californica*, and *Uvigerina peregrina*, occur at all three locations. With these forms, the connection between the east side of the basin and the other two sampled areas is severed. Perhaps this differentiation in faunas is due to the character of the substratum. Rock crops out on the east side of the basin, whereas mud is present on both the sill and the west side.

A fauna dominated by *Bulimina subacuminata* and *Cassidulina translucens* occurs on the east slope. Of the more significant species occurring on the sill, only *Uvigerina ampullacea* is not found also at the western sample location. Species common to the west slope and the sill are: *Bolivina spissa*, *Bolivinita minuta*, *Cassidulina cushmani*, *Cassidulina delicata*, *Epistominella smithi*, *Epistominella levicula*, *Sigmoilina tenuis*, and *Valvulineria araucana*.

Although the foregoing species have a common test distribution, the majority were found living either on the sill or on the western slope (text-fig. 4b). Species living in both locations are *Cassidulina cushmani* and *Epistominella levicula*. Species living only on the sill are *Bolivinita minuta*, *Cassidulina delicata*, and *Virgulina nodosa*. Species living on the west side near sill depth are: *Bolivina spissa*, *Epistominella smithi*, *Globobulimina pacifica*, *Pullenia salisburyi*, *Uvigerina peregrina*, *Valvulineria inaequalis*, and *Virgulina seminuda*. It is interesting to note that almost twice the number of living species present on the sill inhabit the western slope at a comparable depth. Currents affecting the renewal of basin water over the sill may provide an environment in which only certain species can maintain themselves.

The influence of sill level upon the distribution of living species is illustrated by the vertical ranges of species present on the sill (text-fig. 5). With the exception of *Epistominella smithi*, which transects the boundary, there is a distinct tendency for living species to be limited either to the area above or to



TEXT-FIGURE 4

FREQUENCY DISTRIBUTION OF FORAMINIFERA NEAR SILL LEVEL

a, frequency distribution of total population near sill level; b, frequency distribution of living species near sill level.

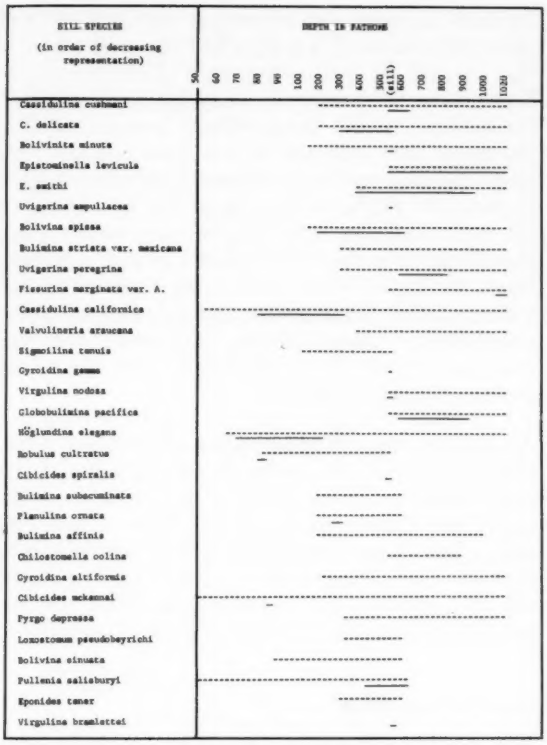
depths below sill level. Non-living specimens generally show a much wider range than do their living counterparts, and are poorly defined in their relationships to sill level.

In addition to the foregoing trends, an analysis of the ranges of all species living below sill level shows that the actual boundary between the deeper basin species and those living above the sill is a zone extending from the sill (at 562 fathoms) down to 600 fathoms (text-fig. 6). *Virgulina seminuda* is a second form spanning this boundary.

The last distributional category to be described is that of foraminifera occurring around the rim of the basin at depths from 50 to 300 fathoms. Although many species occurring at these depths are restricted in lateral distribution, those representing the greater portion of the population are generally found around the entire circumference of the basin. Foraminifera widely distributed throughout this range include: *Angulogerina angulosa*, *Angulogerina hughesi*, *Angulogerina hughesi* var. *picta*, *Cassidulina californica*, *Cassidulina limbata*, *Cassidulina tortuosa*, *Cibicides fletcheri*, *Cibicides refulgens*, *Ehrenbergina compressa*, *Laticarinina pauperata*, *Planulina ariminensis*, and *Poroeponides cribrorepandus*.

Discussion of benthonic distribution

In the Santa Cruz Basin, as in other environments along the California coast, foraminiferal faunas show



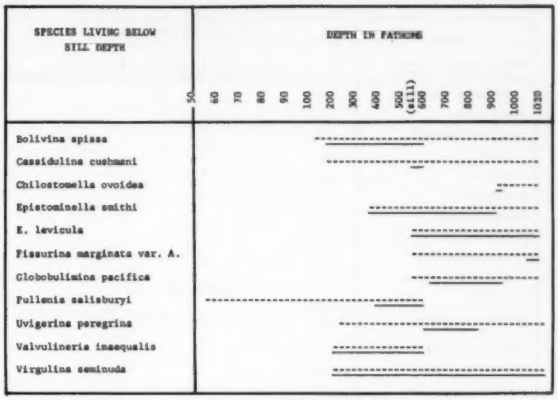
TEXT-FIGURE 5

VERTICAL RANGES OF SILL SPECIES

Solid line indicates range of living specimens; dashed line shows total range of species.

a relationship to depth and temperature. Below sill depth, a definite change in faunal composition occurs, and this fauna, with only a slight tendency toward zonation, is typical of the entire enclosed basin bottom. Because of isothermal water conditions, the slight zonation of living forms observed below sill depth must be attributed to an environmental influence other than temperature. *Chilostomella ovoidea* and *Fissurina marginata* var. *A* appear to be restricted to the greatest basin depths, whereas *Cassidulina cushmani* and *Uvigerina peregrina* are found typically within 200 fathoms of the sill. Four other species span the interval from sill depth to the bottom.

Species living in the basin below sill depth are those found in the bathyal zone (100–1000 fathoms) of the open ocean. Although the basin is of sufficient depth to accommodate some of the upper abyssal species, the absence of living species of this group indicates control of the fauna by the homogeneity of water properties.



TEXT-FIGURE 6

VERTICAL RANGES OF SPECIES LIVING BELOW SILL DEPTH

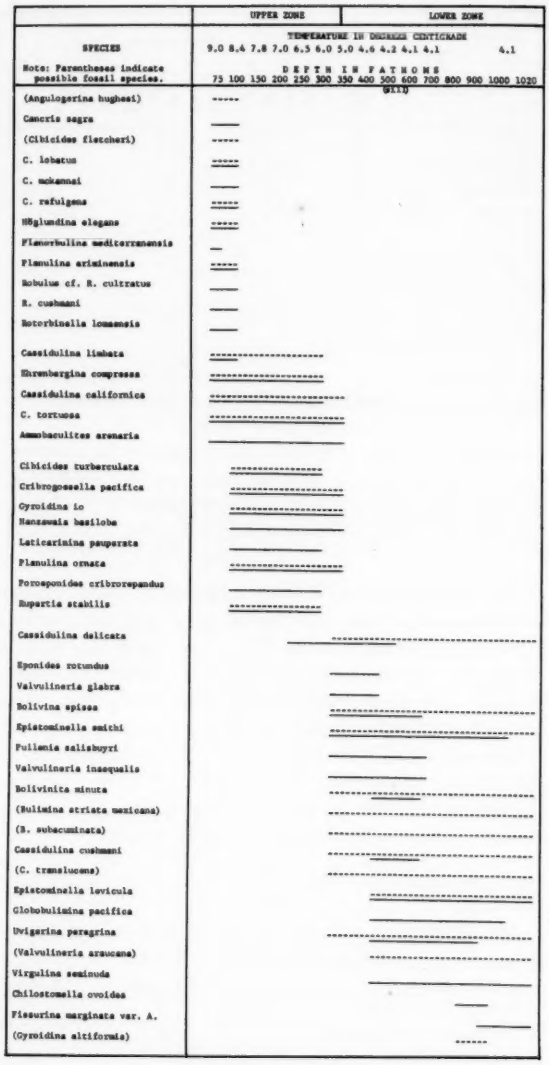
The range of living specimens is shown by a solid line; dashed lines indicate total range of species.

The distribution of living individuals only rarely corresponds to the test distribution of that species. Living individuals, with few exceptions, are found near the upper limit of test accumulations, indicating that downward displacement of empty tests occurs after the death of the animal. A typical shallow-water fauna from near Santa Barbara Island (Table 2) shows very little similarity to the faunas found around the basin rim. Displacement from the island faunas is therefore probably negligible.

TABLE 2

FORAMINIFERAL SPECIES OFF SANTA BARBARA ISLAND AT A DEPTH OF 10 FATHOMS

Species	*Per cent*	*Living*
Angulogerina hughesi	5	
Bolivina advena acutula	3	×
Cibicides fletcheri	10	×
Cibicides gallowayi	1	×
Discorbis posidonicola	2	×
Dyocibicides biserialis	3	×
Elphidium translucens	2	×
Elphidium tumidum	15	×
Elphidium sp.	2	×
Eponides sp.	2	×
Globigerina spp.	9	
Nonionella basispinata	7	×
Quinqueloculina akneriana(?)	3	×
Quinqueloculina angulostriata	5	×
Quinqueloculina neostriatula(?)	5	
Quinqueloculina "seminula" of Cushman and Valentine	4	
Rotorbinella lomaensis	7	×
Valvulineria californica obesa	5	
Others	10	in part



TEXT-FIGURE 7

FAUNAL ZONATION

Solid lines show typical ranges of living species; dashed lines are ranges of important members of the dead population. Abundances of less than one per cent are not included in the ranges of dead species.

Species abundantly represented in the samples have not always been found living, either at the locality where the tests occur or at any place in or surrounding the basin. Fossil tests from the banks appear broken and worn; however, those at greater depths may be as well preserved as are the tests of presently living species. More extensive use of staining techniques may be the only method of differentiating living species from fossil contaminants.

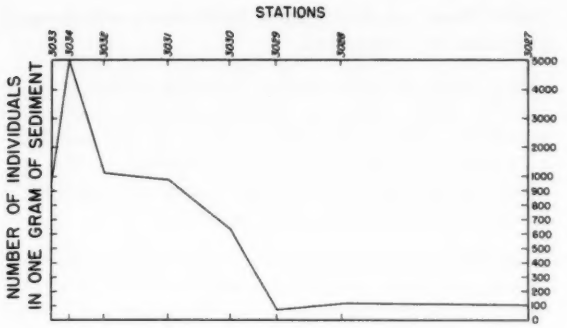
In many samples, the percentage representation of living individuals of a species and the empty tests of that species do not correspond. Throughout the basin there are numerous living species whose representation in the foraminiferal population of a particular area amounts to less than one per cent when the total test accumulation is considered. One explanation might be that some species have long life cycles and slow reproductive rates, so that their contributions to the accumulation of tests would be small. Perhaps a more acceptable explanation involves a factor that is known to exist, that of patchy distribution. Living species with small test representation may have migrated from their true centers of concentration.

Around the rim and upper slopes of the basin, localized faunas may be a result of the character of the substratum, as more variation occurs in the sediments here than at greater depths. Water circulation may affect forms living at deeper locations within the basin. It is thought that currents moving across the sill, creating an active environment, are responsible for the limited living fauna of the sill.

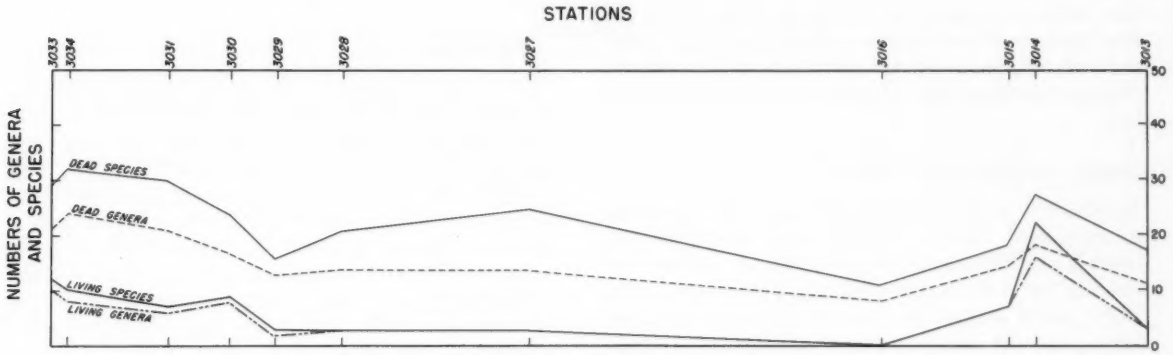
FORAMINIFERAL ZONES

Foraminifera present on the rim of the Santa Cruz Basin and in the basin proper are characteristic of the third and fourth zones of Natland, and of the lower neritic and bathyal zones of Bandy. In this area, the fauna could most easily be divided into an upper zone extending from 75 to 350 fathoms, and a lower zone from 350 to 1020 fathoms (text-fig. 7). Living foraminifera may further exhibit the development of an intermediate zone encompassing approximately the upper 200 fathoms of the lower zone.

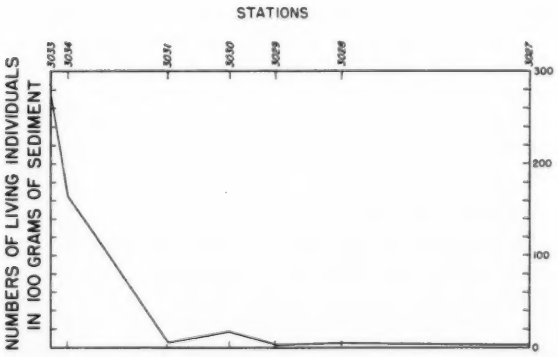
When the zonation of living foraminifera is compared with that of the dead specimens, the following differences are evident: (1) About half of the species important in the formulation of life zones are insignificant in the compositions of the dead populations; (2) one-fourth of the species used in the establishment of death zones have no living representatives; (3) species of the life zones are more restricted in their depth ranges than are those upon which the death zonation is based; and (4) the mass grouping of the fauna into upper and lower zones is applicable to both living and death assemblages. Comparison shows, therefore, that within broad depth ranges, death assemblages can be used for zonation, with the reservation that the presently living population may not be fully represented.



TEXT-FIGURE 8
CONCENTRATION OF FORAMINIFERA



TEXT-FIGURE 9
CONCENTRATION OF GENERA AND SPECIES



TEXT-FIGURE 10
CONCENTRATION OF LIVING INDIVIDUALS

Some of the species present have been reported at other depths in other locations. In his study of Todos Santos Bay, Lower California, Walton found *Höglundina elegans* living at 400 fathoms and deeper. Northward, at Point Arguello, Bandy observed *Höglundina elegans* composing over 10 per cent of the foraminiferal population at approximately 2000 fathoms. Although the latter samples were not preserved, it was thought that the species was living at the place of collection because of its abundance, and because of the fact that it was not found any place higher on the traversed slope. In the Santa Cruz Basin, this species was found living in abundance between 75 and 100 fathoms.

This apparent disregard for environment may possibly be explained in two ways: (1) *Höglundina elegans* may not be living at Point Arguello. In this case, the shallow occurrence of the species on the rim of the Santa Cruz Basin may be due to progressive decrease in depth of habitation with increasing latitude, in response to temperature changes. Temperatures at a depth of 400 fathoms, however, vary only a few tenths of a degree in the two degrees of latitude separating the Santa Cruz Basin from Todos Santos Bay. (2) *Höglundina elegans* may be ecologically dependent upon factors other than temperature. In a reverse situation, Walton found *Cassidulina tortuosa* living at a shallower depth than that which it inhabits in the Santa Cruz Basin. In that case, environmental controls other than temperature appear to govern distribution. This second explanation may best solve the distributional problem.

GENERAL DISTRIBUTIONAL TRENDS

In addition to the zonation of living and non-living foraminifera, several trends were noted in the overall distributional pattern. These trends, involving the distribution of foraminiferal concentrations, genera and species, living individuals, live/dead ratios, and the various types of wall structure, could best be shown in relation to the east-west depth profile used in the frequency diagrams.

Concentration of foraminifera

The number of foraminifera per gram of sediment was shown to decrease with depth, becoming relatively uniform below the sill (text-fig. 8). On the rim and upper slopes of the basin, the number of foraminifera in a gram of sediment may be as much as 70 times the number below sill depth.

Genera and species

In the concentration of genera and species, a relationship to depth is shown by living forms; non-living specimens exhibit a relationship to topography (text-fig. 9). These trends are best shown on the west side of the basin, where a continuous profile of stations and good sampling conditions give a more accurate picture of the faunal distribution than could be obtained on the east side.

Living genera and species on the western basin slope show a slight decrease in numbers with depth until below sill level, where a pronounced reduction occurs. Near the sill, eight or nine genera and species are presently living, whereas below this depth, only two or three are living. A limiting effect of the enclosed basin on the types of individuals which may populate it is suggested.

Along with the decrease in numbers of genera and species, there is also a tendency toward reduction of speciation with depth. Below sill depth, the numbers of genera and species generally coincide, so the enclosed basin environment may also have an effect on the evolution of multiple species.

Non-living genera and species show great reduction down the basin slope followed by an increase in numbers on the basin bottom. Empty foraminiferal tests may therefore accumulate on the floor of the basin after having bypassed the slope area.

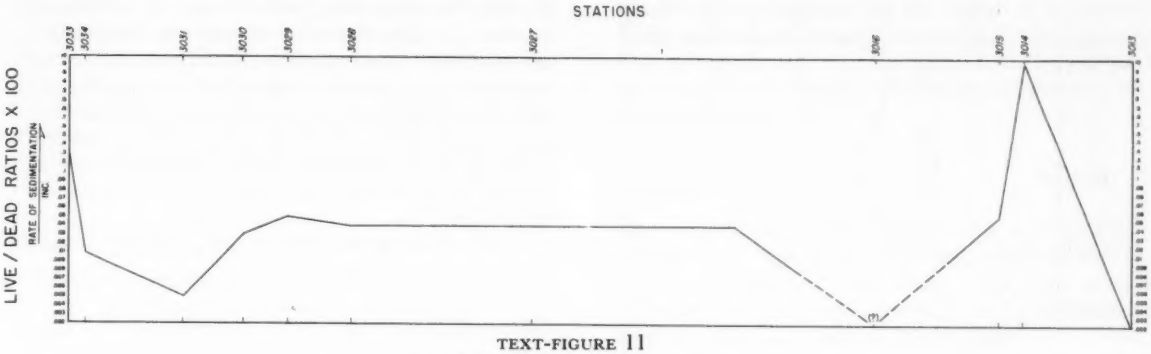
Living individuals

The concentration of living individuals on the western side of the basin was determined by calculating the number of living individuals in 100 grams of sediment (text-fig. 10). In the first 325 fathoms, there is a radical reduction in number from 275 to less than twenty individuals. This number is further reduced to three or four in greater basin depths. Sill level appears to be undefined by the concentration of living forms outside of the conformity in number of living individuals at some distance below sill depth.

L/D ratios

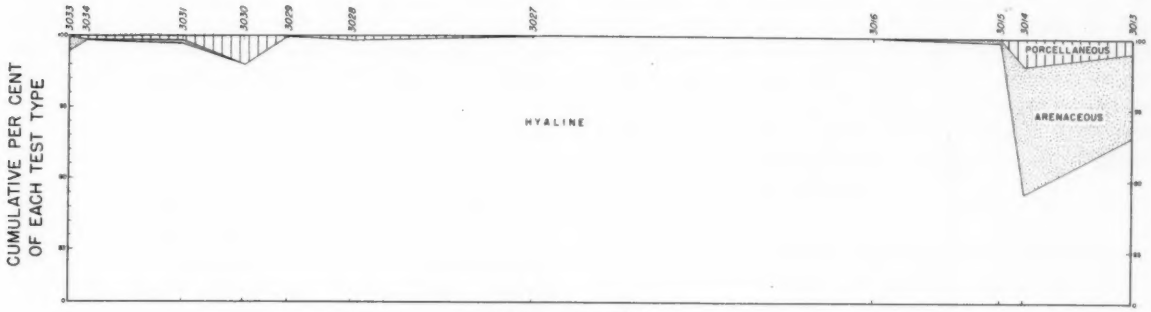
Walton, in his study of ecologies in Todos Santos Bay, noted a relationship between the ratio of live to dead foraminifera and the rate of sedimentation. If this ratio were high, the tests of dead individuals were being buried by rapid sedimentation. Conversely, a low ratio meant slow deposition of sediment, allowing large numbers of tests to accumulate on the surface.

Assuming productivity to be equally distributed, this principle should apply to any area presently inhabited by foraminifera. L/D ratios plotted on a sketch of the east-west profile of the basin (text-fig. 11) show the following results: (1) Very slow deposition on the tops of the banks; (2) a relatively fast rate of sedimentation along the edges of the banks; (3) slow to very slow deposition on the upper slopes; and (4) a medium rate of sedimentation in the enclosed basin. These rates are relative only to each other within the basin area. The fastest rate present would be classified in Walton's group of slowest sedimentation, as he was dealing with an area adjacent to the source of detrital sediments, whereas the Santa Cruz Basin is over 30 miles from the mainland or principal sediment source.



TEXT-FIGURE 11

LIVE/DEAD FORAMINIFERAL RATIOS



TEXT-FIGURE 12

DISTRIBUTION OF TEST TYPES

Test types

The geographic distribution of foraminifera grouped according to wall structure has been shown to exhibit important trends in some areas. Of eleven stations on the east-west profile of the Santa Cruz Basin, seven possess totally hyaline faunas (text-fig. 12). The remainder have hyaline test types representing 89 to 99 per cent of the total population.

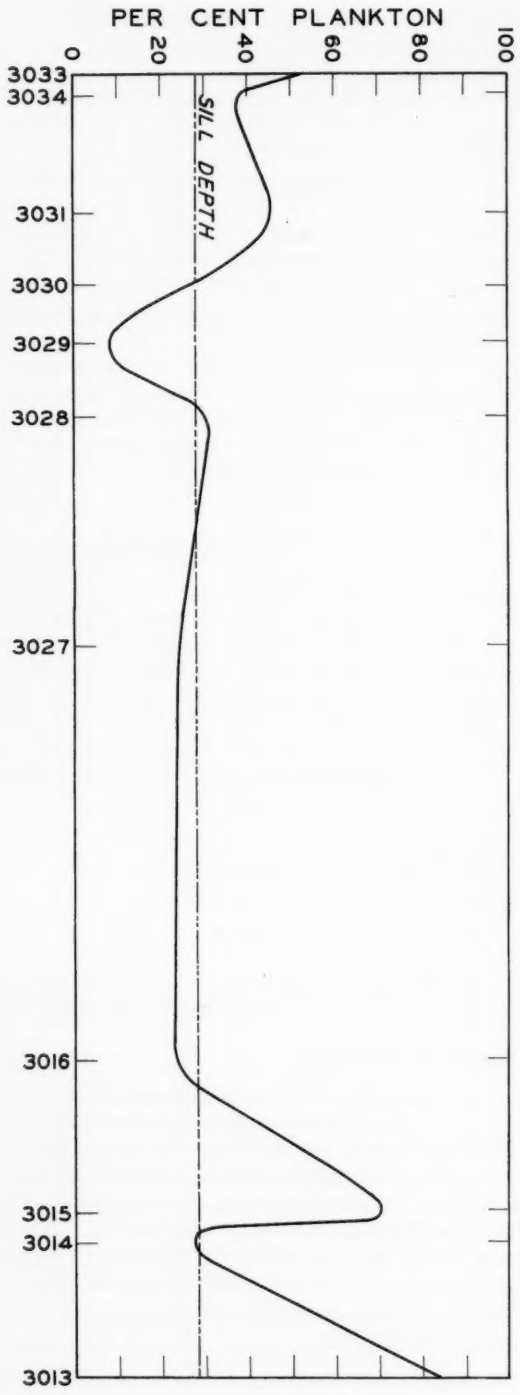
Arenaceous elements appear above 400 fathoms, and are more common on the east side of the basin than on the western slope. Foraminifera with porcellanous tests are generally rare along the basin profile, and again are present above 400 fathoms. The two occurrences of porcellanous tests below this depth are a result of the presence of *Sigmoilina tenuis*, a form which is probably fossil.

Absence of arenaceous and porcellanous forms from the enclosed portion of the basin seems to be a function of depth rather than of the limitations of a basin environment. Both groups cease to appear at depths shallower than the sill level of the basin.

PLANKTONIC FORAMINIFERA

Tests of planktonic foraminifera found in the basin sediments consist mostly of small immature Globigerinas. Because immature specimens are difficult to identify specifically, and because benthonic forms are generally better indicators of environment than planktonic species, no attempt was made to identify the components of the *Globigerina* population. Planktonic forms appearing only rarely in the samples are: *Orbulina universa*, *Globorotalia puncticulata*, and *Globorotalia truncatulinoides*.

Variation in the percentage composition of plankton in the samples is common and in some cases extreme. The planktonic content of stations on the east-west profile of the basin varies more in shallow



TEXT-FIGURE 13
CONCENTRATION OF PLANKTON

water than in the basin depths (text-fig. 13). Current patterns in the shallow waters over the banks and around the islands may concentrate the plankton deposition in selected areas. Shallow-water current patterns may also be responsible for varying rates of sedimentation, which, in turn, would allow for a vast accumulation of tests of planktonic forms in areas of slow sedimentation. Comparison of the plankton curve with the rates of sedimentation as determined by L/D benthonic ratios shows a high concentration of planktonic tests in the areas of slowest sedimentation.

The most remarkable trend exhibited by the planktonic population is a general decrease in concentration with depth, leveling off below the sill. Above sill level, the average plankton content is 52 per cent, whereas below this depth it is less than half this amount, or 23 per cent. Although the figures were calculated on the basis of the total population, comparable results were obtained by comparing the plankton with the indigenous benthonic species only.

In areas of slow sedimentation above sill depth, the abundance of planktonic foraminiferal tests may be partially attributed to a fossil source. The planktonic composition of the location on the west rim exhibiting a fast rate of sedimentation is, however, greater than that of all stations below sill depth. Plankton abundance is therefore a function of present environmental conditions, fortified in some cases by deposits of the past.

The existence of foraminifera in a planktonic environment is controlled by the presence of diatoms, their food supply. Diatoms, in turn, owe their existence to the presence of the plant nutrients, silicates, nitrates, and phosphates. It is the distribution of these plant nutrients that perhaps explains the distribution of planktonic elements in the sediments of the Santa Cruz Basin.

Plant nutrients tend to become concentrated in bottom sediments after the death of planktonic organisms. The nutrients may thereafter be restored to the surface only by upwelling of deep-water masses (Sverdrup, Johnson, and Fleming, 1952, pp. 246–247). In the California offshore area, upwelling would reasonably be expected to occur over the banks, the movement of water masses being blocked by the submerged ridges, forcing deeper waters to rise. The abundance of nutrients over the banks would then favor the growth of populations of phyto- and zooplankton.

Studies of planktonic foraminifera in the Gulf of Mexico have shown that the concentration of planktonic tests may be of great value in ecologic interpretation (Smith, 1955). In the unique environment of a basin, the concentration of planktonic elements may serve to distinguish the sill level and the enclosed portion of the basin. This factor may be extremely important in studies of basins of the past.

FACTORS DISTURBING RECENT DISTRIBUTIONAL PATTERNS

Distribution of foraminifera living in Recent time would be greatly simplified if Recent forms occupied a layer distinctly separate from the former depositional surface, and if, after death, their tests remained in the same area as living representatives of the species. Unfortunately, the ideal condition does not exist in a deep basin environment. Movement of sediment down the slopes not only displaces currently living species, but aids in the mixture of the Recent material with earlier formations as well. As both displacement and contamination of the present foraminiferal fauna were evident in the Santa Cruz Basin, they will be discussed at this time.

Displaced foraminifera

Previous investigations have disclosed the displacement of shallow-water foraminifera into deeper water at several locations along the California coast (Phleger, 1951; Bandy, 1953). The displacement involved either mass transport of faunas or indiscriminate movement of individual members.

Mass displacement of faunas was not evident in any of the basin samples. Tests of individual species, however, were often found at greater depths than those occupied by the living representatives of that species. In the most extreme cases, tests of foraminifera normally occupying a depth of less than 300 fathoms were found scattered down the entire slope and on the basin bottom. The tests were very rare, generally composing less than one per cent of the total population. Species represented in this group are *Cassidulina californica*, *Cassidulina limbata*, and *Höglundina elegans*.

Species living around sill depth are commonly displaced downward after death, thus making the faunal distribution of the enclosed basin appear more homogeneous than is actually the case. The displaced tests of this group compose from one to 34 per cent (average 8 per cent) of the total foraminiferal population at the location of repose. Species exhibiting displacement are *Bolivinita minuta*, *Cassidulina cushmani*, *Cassidulina delicata*, and *Virgulina nodosa*.

The total effect of displacement upon the Recent distributional patterns of the basin is negligible. Maximum displacement, occurring in populations near sill depth, may serve to distinguish the enclosed portion of former basins by creating a nearly uniform fauna below the sill.

Fossil faunas

The occurrence of fossil foraminifera in the surface sediments of the basin may be attributed to: (1) Direct exposure of fossil strata; (2) fossil species reworked into Recent material; and (3) residual faunas, remaining from an earlier age.

Although there are probably many direct exposures of fossil strata on the steep basin slopes, only one was encountered in the limited number of samples secured for this report. This exposure occurs on the western slope of the basin at a depth of 200 fathoms (station 3032). The exposed material, a sandy green mud, resembles Recent sediment below it on the slope. Over 80 per cent of the foraminiferal fauna proved to be Upper Miocene in age. Members of the faunal association dating this outcrop as upper Mohnian are as follows:

Bolivina barbarana Cushman and Kleinpell
Bolivina bramlettei Kleinpell
Bolivina girardensis Rankin var.
Bolivina granti Rankin
Bolivina modesta Galloway and Wissler
Bolivina sinuta Galloway and Wissler var. *alisoensis* Cushman and Adams
Bolivina subadvena Cushman var. *spissa* Cushman (of Kleinpell)
Cassidulina monicana Cushman and Kleinpell
Discorbinella valmonteensis Kleinpell
Gyroidina multicamerata (Kleinpell)
Hopkinsina magnifica Bramlette
Nonion goudkoffi Kleinpell
Uvigerina hootsi Rankin
Valvulineria robusta (Kleinpell)
Valvulineria subinaequalis (Kleinpell)

Fossils reworked into Recent material are quite common in all parts of the basin. Most of the reworked foraminifera are Pliocene in age, but Miocene and Pleistocene forms are also present. Pliocene foraminifera are concentrated on the slopes and basin bottom and are also well represented on the sill. Miocene and Pleistocene species, on the other hand, are commonly found on the upper slopes and bank tops.

Reworked foraminifera from Miocene strata range in age from Luisian to Delmontian (Middle to Upper Miocene). Recorded species include:

Bolivina bramlettei Kleinpell
Bolivina granti Rankin
Bolivina modesta Galloway and Wissler
Bolivina subadvena Cushman var. *spissa* Cushman (of Kleinpell)
Hopkinsina magnifica Bramlette
Siphogenerina nuciformis Kleinpell
Siphogenerina reedi Cushman
Siphonodosaria advena (Cushman and Laiming)
Uvigerina joaquinensis Kleinpell

Species probably reworked from Pliocene material are:

Angulogerina carinata Cushman
Bolivina argentea Cushman
Bolivina interjuncta Cushman
Bolivina interjuncta Cushman var. *bicostata* Cushman
Bolivina sinuata Galloway and Wissler
Bulimina pagoda Cushman
Bulimina rostrata H. B. Brady
Bulimina subacuminata Cushman and R. E. Stewart
Cassidulina lomitensis Galloway and Wissler
Cassidulina translucens Cushman and Hughes
Cibicides mckannai Galloway and Wissler
Cibicides spiralis Natland
Eponides subtener (Galloway and Wissler)
Eponides tener (Brady)
Gyroidina altiformis R. E. Stewart and K. C. Stewart
Plectofrondicularia californica Cushman and R. E. Stewart
Sigmoilina tenuis (Czjzek)
Valvulineria araucana (d'Orbigny)

Possibly reworked from Pleistocene deposits are the following species:

Cibicides fletcheri Galloway and Wissler
Elphidium fax Nicol subsp. *fax* Nicol

What may be a residual Pleistocene fauna occurs on the bank tops. Species which normally occupy shallower depths than are now present and which are common in Pleistocene deposits of other areas may be found in association with presently living forms. The residual fauna is composed of the following species:

Astacolus californicus Galloway and Wissler
Cibicides fletcheri Galloway and Wissler
Cibicides gallowayi Cushman and Valentine
Elphidium fax Nicol subsp. *fax* Nicol
Polymorphina charlottensis Cushman
Sigmomorphina frondiculariformis (Galloway and Wissler)

The three types of fossil contamination of the Recent depositional surface are in evidence along the east-west profile of the basin (text-fig. 14). Distribution of the various age groups is topographic, the pre-basin formations being exposed only on the steep upper slope on the west side of the basin. Since the development of the basin, subsequent deposition has taken place where the angle of repose of the sediments would permit. In such an environment, the mixture of material of several ages is a common occurrence rather than an exception. A complete list of species having no living representatives in the basin area is given with the faunal references.

SUMMARY AND CONCLUSIONS

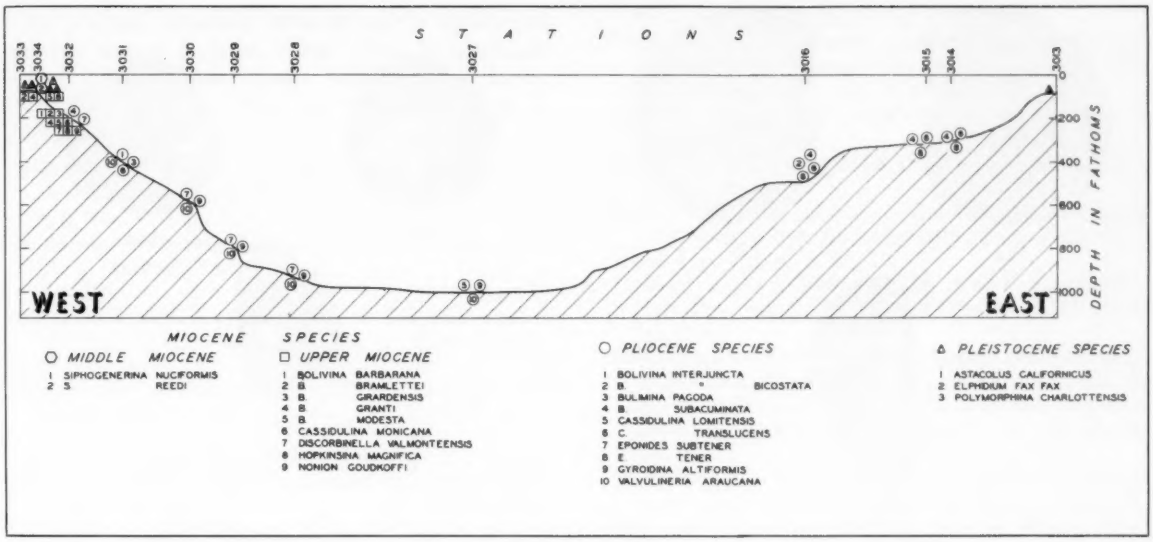
The foraminiferal fauna of the Santa Cruz Basin can be broadly grouped into two depth-temperature zones: An upper zone from the rim of the basin down to 350 fathoms, and a lower zone from 350 fathoms to the basin bottom. Within these zones, living forms occupy more restricted ranges than do their non-living counter-parts, usually being found near the upper limits of test distribution.

Several well-represented species have no living representatives, and many living forms are rare in the total test accumulations. The relative abundance of tests should be used with discretion, therefore, in determining present populations.

Sill level, in controlling the temperature of the water in the enclosed basin, exerts an influence upon the fauna. Living species are generally limited either to the area above or to the depths below sill level. Species living only below sill depth are:

Cassidulina cushmani R. E. Stewart and K. C. Stewart
Chilostomella ovoidea Reuss
Epistominella levicula Resig
Fissurina marginata (Montagu) var. *A*
Globobulimina pacifica Cushman
Uvigerina peregrina Cushman

A slight tendency toward depth zonation is exhibited by species living below the sill. Although the factor responsible for the zonation is not known, isothermal conditions below sill depth eliminate temperature as the controlling agent. Downward displacement of species living near sill depth, after death, may aid in the formation of a nearly homogeneous death assemblage below this level.



TEXT-FIGURE 14

DISTRIBUTION OF FOSSIL SPECIES

The influence of the sill is indicated further in the distribution of genera and species and in the concentration of tests and planktonic elements. Living genera and species decrease slightly in number with depth until below the sill, where a pronounced reduction occurs. The reduced number is then typical of the lower portion of the basin. A limiting effect may be exerted by the enclosed basin environment upon the types of inhabitants and upon subsequent speciation of those forms.

Genera and species of the death assemblage decrease down-slope, then increase in number on the basin floor. The accumulation of displaced tests in bottom sediments is suggested.

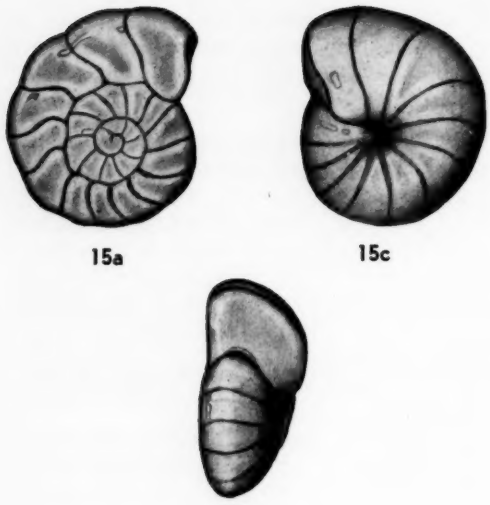
Test concentration shows a relationship to sill level in that after a decrease in concentration with depth, a relatively uniform concentration is maintained below the sill. The rate of sedimentation, as computed from live/dead foraminiferal ratios, is also nearly uniform in the enclosed basin. Assuming the rate of test accumulation to be constant, uniform sedimentary rates would serve to equalize test concentration below the sill.

Planktonic tests show over 50 per cent reduction in concentration in the sediments below sill depth. This has been linked with a greater source of food over the banks, allowing maximum planktonic production above the upper reaches of the basin.

In addition to the depth zonation of species, lateral changes in fauna occur. Localized faunas may be related to the character of the substratum, which is ultimately an effect of the topographic structure of the basin; they may he related to currents, which may exert a decided influence upon the sill fauna; or they may be related to food supply.

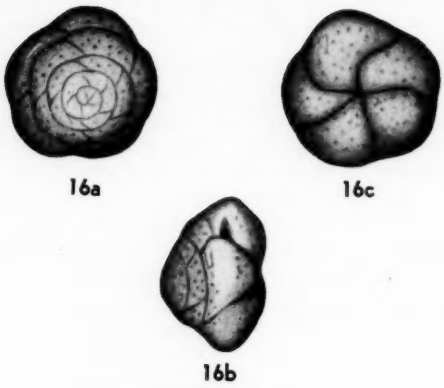
The Recent distributional pattern is complicated by the presence of fossil forms. Fossils from pre-basin strata are present on the steep upper slopes of the basin, whereas post-basin forms may contaminate the interior of the basin and the bank tops.

In conclusion, population studies of the Santa Cruz Basin have made possible the comparison of the distribution of living foraminifera with death assemblages. As only death assemblages are involved in the investigation of former basins, this study has provided some means of associating the observed distribution of fossil species with distributional patterns that may have existed in life. Faunal criteria for recognition of the sill level of a basin may prove to be of great paleoecologic importance.



TEXT-FIGURE 15

Gyroidina io Resig, n. sp., × 72: a, dorsal view; b, edge view; c, ventral view.



TEXT-FIGURE 16

Epistominella levicula Resig, n. sp., × 108: a, dorsal view; b, edge view; c, ventral view.

SYSTEMATIC DESCRIPTIONS

Genus GYROIDINA d'Orbigny, 1826

Gyroidina io Resig, **new species**
Text-figure 15a–c

Test planoconvex, dorsal side flattened, ventral side moderately convex, edge moderately sharp; umbilicus small; two and one-half whorls visible dorsally, ten to twelve chambers in the last whorl; dorsal sutures slightly oblique and slightly curved, flush with the surface; ventral sutures also slightly curved, flush, tending to become broadly limbate toward the umbilicus in the early portion of the test; wall finely perforate, surface polished; aperture a small arched opening midway between the outer edge and the umbilicus, with a small lip. Diameter 0.50 mm.; thickness 0.23 mm.

This species most closely resembles *Gyroidina soldanii* d'Orbigny var. *rotundimargo* R. E. Stewart and K. C. Stewart (1930, Jour. Pal., vol. 4, p. 68), from which it differs in the more compressed test, the greater height of the last septal face, the shallower umbilicus, and the flush sutures.

The type specimens were found living at a depth of 300 fathoms on a rock-sand substratum on the east slope of the Santa Cruz Basin, California.

Holotype: U.S.C. no. 4406.

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

Epistominella levicula Resig, **new species**
Text-figure 16a–c

Test unequally biconvex, deeply convex dorsally, moderately convex ventrally, edge rounded; three and one-half whorls in the dorsal spire, four or five chambers in the final whorl; dorsal sutures oblique, very slightly curved, obscure in the early whorls; ventral sutures curved, somewhat depressed, meeting in the center of the test; wall rather coarsely perforate for the small size of the species; aperture a small slit on the last septal face, elongate parallel to the edge of the test, surrounded by a depression. Diameter 0.20 mm.; thickness 0.15 mm.

The species is similar in appearance to *Eponides pusillus* Parr (1950, B.A.N.Z. Antarctic Res. Exped., Repts., ser. B, vol. 5, pt. 6, p. 360), from which it differs in the character of the aperture and the greater height of the last septal face. It differs from *Epistominella naraensis* (Kuwano) (= *Pseudoparrella naraensis* Kuwano, 1950, Geol. Soc. Japan, Jour., vol. 56, p. 317) in the greater number of whorls in the dorsal spire, in the more curved sutures, and in the more irregular periphery.

Types of this species were found living at depths of 560 to 1020 fathoms in the Santa Cruz Basin, California.

Holotype: U.S.C. no. 4407.

FAUNAL REFERENCES

The original reference to each species mentioned in this report is listed below. Also included are some species which appear repeatedly as traces. Starred species are those not recorded living in the basin samples.

Ammobaculites arenaria Natland, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 139, pl. 3, figs. 7–8.

Ammodiscus minutissimus Cushman and McCulloch, 1939, Allan Hancock Pacific Exped., vol. 6, p. 70, pl. 5, figs. 3–4.

Angulogerina angulosa (Williamson) = *Uvigerina angulosa* Williamson, 1858, Recent Foram. Gt. Britain, p. 67, pl. 5, fig. 140.

**Angulogerina carinata* Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 159, pl. 4, fig. 3.

Angulogerina hughesi (Galloway and Wissler) = *Uvigerina hughesi* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 76, pl. 12, fig. 5.

Angulogerina hughesi (Galloway and Wissler) var. *picta* Todd, 1948, Allan Hancock Pacific Exped., vol. 6, p. 290, pl. 36, fig. 3.

**Anomalina umbilicatula* Heron-Allen and Earland, 1932, Discovery Repts., vol. 4, p. 426, pl. 14, figs. 40–42.

**Astacolus californicus* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 46, pl. 8, fig. 4.

Biloculinella globulus (Bornemann) = *Biloculina globulus* Bornemann, 1855, Deutsch. Geol. Ges., Zeitschr., vol. 7, pt. 2, p. 349, pl. 19, fig. 3.

Bolivina acuminata Natland, 1946, in Cushman and Gray, Cushman Lab. Foram. Res., Spec. Publ. no. 19, p. 34, pl. 5, fig. 46.

Bolivina advena Cushman var. *acutula* Bandy, 1953, Jour. Pal., vol. 27, p. 180, pl. 24, fig. 7.

**Bolivina argentea* Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 42, pl. 6, fig. 5.

**Bolivina barbarana* Cushman and Kleinpell, 1934, ibid., vol. 10, p. 11, pl. 2, fig. 5.

**Bolivina bramlettei* Kleinpell, 1938, Miocene stratigraphy of California, p. 267, pl. 21, figs. 9–11.

Bolivina brevior Cushman, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 31, pl. 5, fig. 8.

**Bolivina girardensis* Rankin, 1934, in Cushman and Kleinpell, ibid., vol. 10, p. 17, pl. 3, fig. 7. Specimens recorded in the present study are probably a variety of this species.

**Bolivina granti* Rankin, 1934, ibid., vol. 10, p. 21, pl. 4, figs. 2–3.

**Bolivina interjuncta* Cushman, 1926, ibid., vol. 2, p. 41, pl. 6, fig. 3.

**Bolivina interjuncta* Cushman var. *bicostata* Cushman, 1926, ibid., vol. 2, p. 42.

**Bolivina modesta* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 71, pl. 11, fig. 8.

Bolivina pacifica Cushman and McCulloch, 1942, Allan Hancock Pacific Exped., vol. 6, p. 185, pl. 21, figs. 2–3.

**Bolivina sinuata* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 71, pl. 11, fig. 9.

**Bolivina sinuata* Galloway and Wissler var. *alisoensis* Cushman and Adams, 1935, Cushman Lab. Foram. Res., Contr., vol. 11, p. 19, pl. 3, fig. 5.

Bolivina spissa Cushman, 1926, ibid., vol. 2, p. 45, pl. 6, fig. 8.

Bolivina tongi Cushman, 1929, ibid., vol. 5, p. 93, pl. 13, fig. 29.

Bolivinita minuta (Natland) = *Bolivina minuta* Natland, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 146, pl. 5, fig. 10.

**Bulimina affinis* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 109, pl. 2, figs. 25–26.

Bulimina barbata Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 151, pl. 2, fig. 11.

Bulimina denudata Cushman and Parker, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 57, pl. 10, figs. 1–2.

**Bulimina pagoda* Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 152, pl. 2, fig. 16.

**Bulimina pyrula* d'Orbigny var. *spinescens* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 400.

**Bulimina rostrata* Brady, 1884, ibid., vol. 9, p. 408, pl. 51, figs. 14–15.

**Bulimina striata* d'Orbigny var. *mexicana* Cushman, 1922, U.S. Nat. Mus., Bull. 104, pt. 3, p. 95, pl. 21, fig. 2.

**Bulimina subacuminata* Cushman and R. E. Stewart, 1930, San Diego Soc. Nat. Hist., Trans., vol. 6, p. 65, pl. 5, figs. 2–3.

Buliminella elegantissima (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 51, pl. 7, figs. 13–14.

**Buliminella tenuata* Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 149, pl. 2, fig. 9.

Cancris sagrai (d'Orbigny) = *Rotalina* (*Rotalina*) *sagra* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminifères, p. 77, pl. 5, figs. 13–15.

**Cassidulina californica* Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 12, pl. 2, fig. 1.

Cassidulina cushmani R. E. Stewart and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 71, pl. 9, fig. 5.

Cassidulina delicata Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 168, pl. 6, fig. 5.

Cassidulina limbata Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 12, pl. 2, fig. 2.

**Cassidulina lomitensis* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 79, pl. 12, fig. 10.

**Cassidulina monicana* Cushman and Kleinpell, 1934, Cushman Lab. Foram. Res., Contr., vol. 10, p. 16, pl. 3, fig. 4.

Cassidulina subglobosa Brady, 1881, Quart. Jour. Micr. Sci., new ser., vol. 21, pt. 3, p. 60. This species is rare, as compared with *Cassidulina californica*, and was included with the latter in frequency counts.

Cassidulina tortuosa Cushman and Hughes, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 14, pl. 2, fig. 4.

**Cassidulina translucens* Cushman and Hughes, 1925, ibid., vol. 1, p. 15, pl. 2, fig. 5.

**Cassidulinoides simplex* Cushman and Todd, 1945, Cushman Lab. Foram. Res., Spec. Publ., no. 15, p. 63.

Chilostomella czizeki Reuss, 1850, K. Akad. Wiss. Wien, Denkschr., vol. 1, p. 380, pl. 48, fig. 13.

**Chilostomella oolina* Schwager, 1878, in Stohr, R. Com. Geol. Ital., Boll., vol. 9, p. 513, no. 107.

Chilostomella ovoidea Reuss, 1850, K. Akad. Wiss. Wien, Denkschr., vol. 1, p. 380, pl. 48, fig. 12.

Cibicides fletcheri Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 64, pl. 10, figs. 8–9.

Cibicides gallowayi Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, p. 30, pl. 10, fig. 4.

Cibicides lobatus (d'Orbigny) [(Montagu)] = *Truncatulina lobata* [(Montagu)] d'Orbigny, 1839, in Barker-Webb and Berthelot, Hist. Nat. Îles Canaries, "Foraminifères," vol. 2, pt. 2, p. 134, pl. 2, figs. 22–24.

Cibicides mckannai Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 65, pl. 10, figs. 5–6.

Cibicides refulgens Montfort, 1808, Conch. Syst., vol. 1, p. 123.

**Cibicides spiralis* Natland, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 151, pl. 7, fig. 7.

Cibicides tuberculata Natland, 1938, ibid., vol. 4, p. 152, pl. 7, fig. 8.

Cribrogoësella pacifica Cushman and McCulloch, 1935, Allan Hancock Pacific Exped., vol. 6, p. 99, pl. 10, figs. 10–12.

**Discorbinella valmonteensis* Kleinpell, 1938, Miocene stratigraphy of California, p. 350, pl. 21, figs. 14–16.

Discorbis posidonicola Colom, 1942, Inst. Español Oceanogr., Notas y Resum., ser. 2, no. 108, p. 37, pl. 7, figs. 149–150, 152–153.

Dyocibicides biserialis Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, p. 31, pl. 10, figs. 1–2.

Eggerella advena (Cushman) = *Verneuilina advena* Cushman, 1922, Contr. Canadian Biol., no. 9, p. 141.

Ehrenbergina compressa Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 168, pl. 6, fig. 7.

**Elphidium fax* Nicol subsp. *fax* Nicol, 1944, Jour. Pal., vol. 18, p. 177.

Elphidium translucens Natland, 1938, Scipps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 144, pl. 5, figs. 3–4.

Elphidium tumidum Natland, 1938, ibid., vol. 4, p. 144, pl. 5, figs. 5–6.

**Epistominella bradyana* (Cushman) = *Pulvinulinella bradyana* Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 165, pl. 5, figs. 11–13.

Epistominella levicula Resig, n. sp., this paper, text-fig. 16a–c.

Epistominella smithi (R. E. Stewart and K. C. Stewart) = *Pulvinulinella smithi* R. E. Stewart and K. C. Stewart, Jour. Pal., vol. 4, p. 70, pl. 9, fig. 4.

Eponides rotundus Husezima and Maruhasi, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 399, pl. 34, fig. 12.

**Eponides subtener* (Galloway and Wissler) = *Rotalia subtenera* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 60, pl. 10, fig. 4.

**Eponides tener* (Brady) = *Truncatulina tenera* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 665, pl. 95, fig. 11.

Fissurina sp.: Test hyaline, unilocular, only slightly compressed; wall finely perforate, thick for the genus, ornamented by eight low ribs on each side, which become obscure toward the aperture; aperture fissurine, at the end of a short, compressed neck. Length 0.3–0.5 mm.

Fissurina marginata (Montagu) var. *A:* Test hyaline, unilocular, compressed, shape circular to oval, edge sharp and thickened; wall finely perforate, thin, transparent over the central portion; aperture fissurine, at the end of a very short neck. Length 0.3–0.4 mm.

Fissurina marginata (Montagu) var. *B:* Test hyaline, unilocular, highly compressed, shape oval, becoming pointed on the apertural end, edge sharp, slightly carinate; wall finely perforate, thin; aperture fissurine, short; entosolenian tube visible. Length 0.3 mm.

Fissurina marginata (Montagu) var. *C:* Test hyaline, unilocular, compressed, shape of chamber nearly circular, test shape appearing oval because of neck, edge sharp with carinae approximately one-fifth of the width of the test; wall finely perforate, thin; aperture fissurine, at the end of a carinate neck. Length 0.5–0.7 mm.

**Gaudryina subglabrata* Cushman and McCulloch, 1939, Allan Hancock Pacific Exped., vol. 6, p. 92, pl. 8, figs. 5–7.

Gaudryina atlantica (Bailey) var. *pacifica* Cushman and McCulloch, 1939, ibid., vol. 6, p. 94, pl. 9, figs. 1–2.

Globobulimina pacifica Cushman, 1927, Cushman Lab. Foram. Res., Contr., vol. 3, p. 67, pl. 14, fig. 12.

**Globorotalia puncticulata* (d'Orbigny) = *Globigerina puncticulata* d'Orbigny in Deshayes, 1832, Ency. Méth., vol. 2, pt. 2, p. 170.

**Globorotalia truncatulinoides* (d'Orbigny) = *Rotalina truncatulinoides* d'Orbigny, 1839, Hist. Nat. Îles Canaries, vol. 2, pt. 2, p. 132, pl. 2, figs. 25–27.

Gyroidina altiformis R. E. Stewart and K. C. Stewart = *Gyroidina soldanii* d'Orbigny var. *altiformis* R. E. Stewart and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 67, pl. 9, fig. 2.

**Gyroidina gemma* Bandy, 1953, ibid., vol. 27, p. 179, pl. 23, fig. 4.

Gyroidina io Resig, n. sp., this paper, text-fig. 15a–c.

**Gyroidina multicamerata* (Kleinpell) = *Eponides multicamerata* Kleinpell, 1938, Miocene stratigraphy of California, p. 320, pl. 19, figs. 2–3, 7.

Hanzawaia cf. *H. basiloba* (Cushman) = *Truncatulina basiloba* Cushman, 1918, U. S. Geol. Survey, Bull. 676, p. 64, pl. 21, fig. 2.

Höglundina elegans (d'Orbigny) = *Rotalia (Turbinuline) elegans* d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 276, no. 54.

**Hopkinsina magnifica* Bramlette, 1951, U. S. Geol. Survey, Prof. Paper no. 222, p. 59, pl. 22, figs. 1–3, 5.

Laticarinina pauperata (Parker and Jones) = *Pulvinulina repanda* (Fichtel and Moll) var. *menardii* (d'Orbigny) subvar. *pauperata* Parker and Jones, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 395, pl. 16, figs. 50–51.

**Loxostomum pseudobeyrichi* (Cushman) = *Bolivina pseudobeyrichi* Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 45.

Miliolinella sublineata (Brady) = *Miliolina circularis* var. *sublineata* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 169.

**Nonion goudkoffi* Kleinpell, 1938, Miocene stratigraphy of California, p. 231, pl. 20, figs. 2, 5.

Nonionella basispinata (Cushman and Moyer) = *Nonion pizarrensis* Berry var. *basispinata* Cushman and Moyer, 1930, Cushman Lab. Foram. Res., Contr., vol. 6, p. 54, pl. 7, fig. 18.

Nonionella miocenica Cushman var. *stella* Cushman and Moyer, 1930, ibid., vol. 6, p. 56, pl. 7, fig. 17.

**Orbulina universa* d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 3, pl. 1, fig. 1.

Planorbulina mediterranensis d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 280, pl. 14, figs. 4–6.

Planulina ariminensis d'Orbigny, 1826, ibid., vol. 7, p. 280, pl. 14, figs. 1–3; modèle no. 49. Specimens recorded in the present study are probably a variation of this species.

Planulina depressa (d'Orbigny) = *Truncatulina depressa* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 39, pl. 6, figs. 4–6.

Planulina ornata (d'Orbigny) = *Truncatulina ornata* d'Orbigny, 1839, ibid., vol. 5, pt. 5, p. 40, pl. 6, figs. 7–9.

**Plectofrondicularia californica* Cushman and R. E. Stewart, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 39, pl. 6, figs. 9–11.

**Polymorphina charlottensis* Cushman, 1925, ibid., vol. 1, p. 41, pl. 6, fig. 9.

Poroeponides cribrorepandus Asano and Uchio, in Asano, 1951, Illustr. catalogue of Japanese Tertiary smaller foraminifera, pt. 14, p. 18, text-figs. 134–135.

Pullenia salisburyi R. E. Stewart and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 72, pl. 8, fig. 2.

**Pyrgo depressa* (d'Orbigny) = *Biloculina depressa* d'Orbigny, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 298; modèle no. 91.

Quinqueloculina akneriana d'Orbigny, 1846, Foram. foss. Bass. Tert. Vienne, p. 290, pl. 18, figs. 16–21.

Quinqueloculina angulostriata Cushman and Valentine, 1930, Stanford Univ., Dept. Geol., Contr., vol. 1, p. 12, pl. 2, fig. 5.

**Quinqueloculina neostriatula* Thalmann, 1950, Cushman Found. Foram. Res., Contr., vol. 1, pts. 3–4, p. 45.

**Quinqueloculina seminulum* (Linné) = *Serpula seminulum* Linné, 1758, Systema naturae, ed. 10, vol. 1, p. 786.

Reophax excentricus Cushman, 1910, U. S. Nat. Mus., Bull. no. 71, p. 92, text-fig. 134.

Robulus cf. *R. cultratus* Montfort, 1808, Conch. Syst., vol. 1, p. 215, 54th genus.

Robulus cushmani Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 51, pl. 8, fig. 11.

Rotorbinella lomaensis (Bandy) = *Rotalia lomaensis* Bandy, 1953, ibid., vol. 27, p. 179, pl. 22, fig. 6.

Rupertia stabilis Wallich, 1877, Ann. Mag. Nat. Hist., ser. 4, vol. 19, p. 301, pl. 20.

**Sigmoilina tenuis* (Czjzek) = *Quinqueloculina tenuis* Czjzek, 1848, Naturw. Abh., vol. 2, pt. 1, p. 149, pl. 13, figs. 31–34.

**Sigmomorphina frondiculariformis* (Galloway and Wissler) = *Polymorphina frondiculariformis* Galloway and Wissler, 1927, Jour. Pal., vol. 1, p. 55, pl. 5, fig. 6.

**Siphogenerina nuciformis* Kleinpell, 1938, Miocene stratigraphy of California, p. 303, pl. 15, figs. 10, 12.

**Siphogenerina reedi* Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 1, p. 3, pl. 4, fig. 4.

**Siphonodosaria advena* (Cushman and Laiming) = *Nodogenerina advena* Cushman and Laiming, 1931, Jour. Pal., vol. 5, p. 106, pl. 11, fig. 19.

Textularia sp.: Test arenaceous, biserial, compressed, edge sharp; five or six pairs of chambers, chambers increasing only slightly in height as added, increasing rapidly in length, last chamber three times as long as high; sutures straight, depressed, wall finely arenaceous with a few coarse grains; aperture a slit at the base of the last septal face. Length 0.6 mm.

Triloculina longissima Galloway and Heminway, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, vol. 3, pt. 4, p. 308, pl. 3, fig. 7. Specimens recorded in the present study are probably a variety of this species.

**Triloculina trigonula* (Lamarck) = *Miliolites trigonula* Lamarck, 1804, Paris, Mus. National Hist. Nat., Ann., vol. 5, p. 351; 1807, ibid., vol. 9, pl. 17, fig. 4.

Trochammina charlottensis Cushman, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 39, pl. 6, fig. 4.

Trochammina discorbis Earland, 1934, Discovery Repts., vol. 10, p. 104, pl. 3, figs. 28–31.

**Uvigerina ampullacea* Brady, 1884, Rept. Voy. Challenger, Zool., vol. 9, p. 579, pl. 75, figs. 10–11.

**Uvigerina hollicki* Thalmann, 1950, Cushman Found. Foram. Res., Contr., vol. 1, pts. 3–4, p. 45.

**Uvigerina hootsi* Rankin, 1934, in Cushman and Kleinpell, Cushman Lab. Foram. Res., Contr., vol. 10, p. 22, pl. 3, figs. 8–9.

**Uvigerina joaquinensis* Kleinpell, 1938, Miocene stratigraphy of California, p. 296, pl. 17, figs. 6, 10–11.

Uvigerina peregrina Cushman, 1923, U. S. Nat. Mus., Bull. 104, pt. 4, p. 166, pl. 42, figs. 7–10.

**Valvulineria araucana* (d'Orbigny) = *Rosalina araucana* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 44, pl. 6, figs. 16–18.

**Valvulineria californica* Cushman var. *obesa* Cushman, 1926, Cushman Lab. Foram. Res., Contr., vol. 2, p. 61, pl. 9, fig. 2.

Valvulineria glabra Cushman, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, p. 161, pl. 4, figs. 5–6.

Valvulineria inaequalis (d'Orbigny) = *Valvulina inaequalis* d'Orbigny, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 48, pl. 7, figs. 10–12.

**Valvulineria robusta* (Kleinpell) = *Baggina robusta* Kleinpell, 1938, Miocene stratigraphy of California, p. 325, pl. 11, fig. 8.

**Valvulineria subinaequalis* (Kleinpell) = *Baggina subinaequalis* Kleinpell, 1938, ibid., p. 326, pl. 19, figs. 6, 9, 12.

**Virgulina bramlettei* Galloway and Morrey, 1929, Bull. Amer. Pal., vol. 15, no. 55, p. 37, pl. 5, fig. 14.

Virgulina nodosa R. E. Stewart and K. C. Stewart, 1930, Jour. Pal., vol. 4, p. 64, pl. 8, fig. 4.

Virgulina seminuda Natland, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 145, pl. 5, fig. 12.

BIBLIOGRAPHY

BANDY, O. L.
1953 – *Ecology and paleoecology of some California foraminifera; Part I – The frequency distribution of Recent foraminifera off California.* Jour. Pal., vol. 27, no. 2, pp. 161–182.

BREMNER, C. ST. J.
1932 – *Geology of Santa Cruz Island, Santa Barbara County, California.* Santa Barbara Mus. Nat. Hist., Occas. Papers, no. 1, 33 pp.

BUTCHER, W. S.
1951 – *Foraminifera, Coronado Bank and vicinity, California.* Scripps Inst. Oceanogr., Submarine Geol. Rept., no. 19, pp. 1–9.

CHURCH, C. C.
1929 – *Some Recent shallow water foraminifera dredged near Santa Catalina Island, California.* Jour. Pal., vol. 3, no. 3, pp. 302–305.

CROUCH, R. W.
1952 – *Significance of temperature on foraminifera from deep basins off Southern California coast.* Amer. Assoc. Petr. Geol., Bull., vol. 36, no. 5, pp. 807–843.

CUSHMAN, J. A.
1927 – *Recent foraminifera off the west coast of America.* Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, pp. 119–188.

CUSHMAN, J. A., AND GRAY, H. B.
1946 – *A foraminiferal fauna from the Pliocene of Timms Point, California.* Cushman Lab. Foram. Res., Spec. Publ. no. 19, 46 pp.

CUSHMAN, J. A., AND MCCULLOCH, I.
1939 – *A report on some arenaceous foraminifera.* Allan Hancock Pacific Exped., vol. 6, no. 1, pp. 1–113.
1940 – *Some Nonionidae in the collections of the Allan Hancock Foundation.* Ibid., vol. 6, no. 3, pp. 145–178.
1942 – *Some Virgulininae in the collections of the Allan Hancock Foundation.* Ibid., vol. 6, no. 4, pp. 179–230.
1948 – *The species of Bulimina and related genera in the collections of the Allan Hancock Foundation.* Ibid., vol. 6, no. 5, pp. 231–294.
1950 – *Some Lagenidae in the collections of the Allan Hancock Foundation.* Ibid., vol. 6, no. 6, pp. 295–364.

CUSHMAN, J. A., AND MOYER, D. A.
1930 – *Some Recent foraminifera from off San Pedro, California.* Cushman Lab. Foram. Res., Contr., vol. 6, pt. 3, pp. 49–62.

CUSHMAN, J. A., AND VALENTINE, W. W.
1930 – *Shallow-water foraminifera from the Channel Islands of Southern California.* Stanford Univ., Dept. Geol., Contr., vol. 1, no. 1, pp. 1–31.

EMERY, K. O.
1954 – *Source of water in basins off Southern California.* Jour. Marine Research, vol. 13, no. 1, pp. 1–21.

EMERY, K. O., AND RITTENBERG, S. C.
1952 – *Early diagenesis of California basin sediments in relation to origin of oil.* Amer. Assoc. Petr. Geol., Bull., vol. 36, no. 5, pp. 735–806.

GALLOWAY, J. J., AND WISSLER, S. G.
1927 – *Pleistocene foraminifera from the Lomita Quarry, Palos Verdes Hills, California.* Jour. Pal., vol. 1, no. 1, pp. 35–87.

GRADY, J. R.
[MS.] *The geology of Santa Barbara Island and vicinity.* Southern California, Univ., master's thesis (in preparation).

LALICKER, C. G., AND MCCULLOCH, I.
1940 – *Some Textulariidae of the Pacific Ocean.* Allan Hancock Pacific Exped., vol. 6, no. 2, pp. 115–143.

NATLAND, M. L.
1933 – *The temperature and depth distribution of some Recent and fossil foraminifera in the Southern California region.* Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 3, no. 10, pp. 225–230.

NORRIS, R. M.
1951 – *The marine geology of San Nicolas Island region, California.* Scripps Inst. Oceanography, Submarine Geol. Rept., no. 21, 14 pp.

PHLEGER, F. B
1951 – *Displaced foraminifera faunas.* Soc. Econ. Pal. Min., Spec. Publ. no. 2, pp. 66–75.

RAITT, R. W.
1949 – *Studies of ocean-bottom structure off Southern California with explosive waves.* Geol. Soc. Amer., Bull., vol. 60, p. 1915.

RITTENBERG, S. C., EMERY, K. O., AND ORR, W. L.
1955 – *Regeneration of nutrients in sediments of marine basins.* Deep-Sea Research, vol. 3, pp. 23–45.

SHEPARD, F. P., AND EMERY, K. O.
1941 – *Submarine topography off the California coast: Canyons and tectonic interpretation.* Geol. Soc. Amer., Spec. Paper no. 31, 171 pp.

SMITH, F. D., JR.
1955 – *Foraminifera as indicators of depositional environment.* Micropaleontology, vol. 1, no. 2, pp. 147–151.

SVERDRUP, H. U., AND FLEMING, R. H.
1941 – *The waters off the coast of Southern California, March to July, 1937.* Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, pp. 261–378.

SVERDRUP, H. U., JOHNSON, M. W., AND FLEMING, R. H.
1952 – *The oceans.* Ed. 4. New York: Prentice-Hall, 1060 pp.

UCHUPI, E.
[MS.] *Submarine geology of the Santa Rosa–Cortes Ridge.* Southern California, Univ., master's thesis (1954), 72 pp.

WALTON, W. R.
1952 – *Techniques for recognition of living foraminifera.* Cushman Found. Foram. Res., Contr., vol. 3, pt. 2, pp. 56–60.
1955 – *Ecology of living benthonic foraminifera, Todos Santos Bay, Baja California.* Jour. Pal., vol. 29, no. 6, pp. 952–1018.

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ABSTRACT: *Calcareous plates from the Upper Bathonian (Middle Jurassic) of the Dorset coast, England, doubtfully placed in the Holothuroidea and previously referred to* Etheridgella *sp., are redescribed as* Frizzellus irregularis, *n. gen., n. sp. A statistical study of* Frizzellus *n. gen.* (qua "*parataxon*") *shows it to be a normally distributed coherent unit of a zoological genus within the sections and localities studied.*

Frizzellus irregularis, a new holothurian sclerite from the Upper Bathonian of the Dorset coast, England

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INTRODUCTION

The calcareous plates described in this paper were first encountered by the author during a preliminary investigation of holothurian sclerite assemblages from the Bathonian (Middle Jurassic) of the Dorset coast, England (Hampton, 1957). At that time they were referred to *Etheridgella* sp. and tentatively compared with the North American Pennsylvanian form *Etheridgella porosa* Croneis. Later, topotype material was sent (Hampton, personal communication, 1957) to Don L. Frizzell, of the Missouri School of Mines and Metallurgy, who was able to make comparisons with authentic examples of *Etheridgella porosa*. As a result of this comparison, Frizzell and Exline (Frizzell, personal communication, 1957) completely agree that the Bathonian species conforms to the family Etheridgellidae as they would recognize it; further, they found the species generically distinct from *Etheridgella*, and, as it appears to form a coherent unit, suggested that a new genus be proposed for it. Following Frizzell's (*op. cit.*) suggestion, therefore, a new genus, *Frizzellus*, is erected for the Bathonian specimens, to be included in the forthcoming *Treatise on Invertebrate Paleontology*.

HORIZONS, LOCALITIES AND MATERIAL

The general stratigraphic sequence of the Upper Bathonian beds examined is shown in text-figure 1, as is the relative position of the samples collected containing *Frizzellus*, n. gen. The sections given are incomplete for both localities, and show only the extent of the exposures that yielded the sclerites in question. The coastal localities collected from include: Watton Cliff, near West Bay, Dorset (locality 1 of Hampton, 1957, p. 507); and Herbury Point, near Fleet, Dorset (locality 2, *op. cit.*). *Frizzellus* occurs fairly consistently in association with other holothurian sclerites and microfaunal elements throughout the 25 feet or so of beds studied; in all, twenty-six specimens of the genus were obtained. Numbers preceded by the letter "E" in the following sections of the text denote figured material deposited in the collections of the Department of Palaeontology, British Museum (Natural History), London.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA

Class HOLOTHUROIDEA

Family ETHERIDGELLIDAE Frizzell and Exline, 1955

Genus **Frizzellus** Hampton, **new genus**

Etheridgella Croneis. – HAMPTON, 1957, Geol. Mag., vol. 94, no. 6, p. 510.

Type species: Frizzellus irregularis Hampton, n. sp.

Diagnosis: Imperforate, flat to concavo-convex plates (disks), with irregular hexagonal to subcircular outline and denticulate margin; surface ornamentation of minute granular projections.

Stratigraphic distribution: Middle Jurassic (Upper Bathonian, "*Wagnericeras arbustigerum* zone"), Upper Fuller's Earth Clay and Forest Marble; and Upper Jurassic (Lower Oxfordian, *Cardioceras cordatum* zone), Upper Oxford Clay of the Dorset coast, England.

Discussion: Frizzellus, n. gen., is placed in the family Etheridgellidae on account of its imperforate plate-like structure, and although it was previously referred to *Etheridgella* sp. (Hampton, 1957), it differs from that genus in lacking the characteristic ornamentation of polygonal depressions and pseudospire of the type species, *Etheridgella porosa* Croneis. The assignment of *Frizzellus* to the Holothuroidea is somewhat uncertain, as Frizzell and Exline (Frizzell, personal communication, 1957) have extracted "generically" indistinguishable plates from Recent ophiuroids. Deflandre-Rigaud (1952), however, placed *Etheridgella* in the superorder "Actinopoda," which included the Recent Holothuroidea Dendrochirotida, Aspidochirotida, and Elasipodida (Frizzell and Exline, 1955, p. 92). Further, as *Frizzellus* appears to be related to *Etheridgella* and was found in close association with other holothurian sclerites, such as *Achistrum (Achistrum) bathonianum* Frizzell and Exline; *Achistrum (Cancellrum) gamma* Hodson, Harris and Lawson; *Achistrum (Cancellrum) monochordata* Hodson, Harris and Lawson; *Achistrum (Aduncrum) cordatum* Hampton; and *Rhabdotites? rectus* Frizzell and Exline (Hampton, 1957), its placement in this class is favoured. Hodson, Harris and Lawson (1956, p. 343) described plates from the Lower Oxfordian of Redcliff, near Weymouth, Dorset, as doubtfully holothurian, and these may now be referred to *Frizzellus*. Ophiuroidea are extremely rare in the British Jurassic except from the Middle Liassic (Domerian) *Amaltheus margaritatus* zone, where specimens of the genus *Ophioderma* occur commonly at a well defined level (the "Starfish Bed"), which is exposed on the Dorset coast near Eype (Chatwin, 1948, p. 9).

Remarks: The generic name is given in honour of Professor Don L. Frizzell.

Frizzellus irregularis Hampton, **new species**

Plate 1, figures 1–30

Etheridgella sp., HAMPTON, 1957, Geol. Mag., vol. 94, no. 6, p. 510, text-figs. 11–12.

Description: Sclerites in the form of solid, flat, occasionally concavo-convex plates, with extremely irregular basic hexagonal to subcircular outline and variably denticulate margin; surface ornamentation characterised by very fine, irregular, sometimes more regular, granular projections; maximum diameter 0.52 mm.

Type level and locality: Sample W3 (see text-fig. 1), approximately 9 feet below the *Rhynchonella (Goniorhynchia) boueti* bed (the base of the Forest Marble), Upper Fuller's Earth Clay (Bathonian) of Watton Cliff, near West Bay, Dorset, England (locality 1 of Hampton, 1957, p. 507).

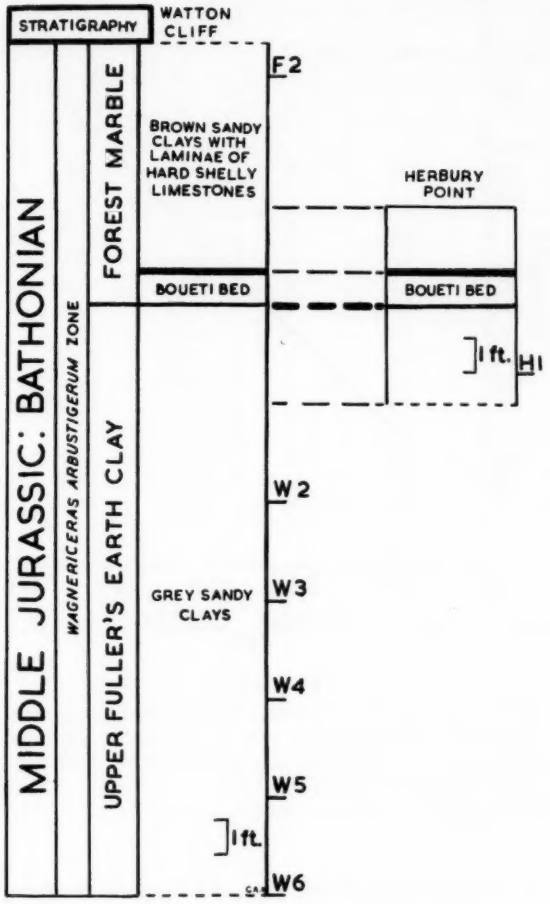
TABLE 1

DIMENSIONS (IN MM.) OF *Frizzellus irregularis*, N. GEN., N. SP.

Sample number	B.M. (N.H.) P.D. no.	Maximum diameter	Mean max. diam. of specimens per sample
H1	E27045	0.26	0.26
	E27046	0.26	
F2	E27047	0.40	—
W2	E27048	0.33	0.37
	E27049	0.36	
	E27050	0.45	
	E27051	0.31	
	E27052	0.38	
	E27053	0.45	
	E27054	0.36	
	E27043	0.35	
W3	E27055	0.36	0.45
	E27056	0.45	
	E27057	0.50	
	E27058	0.52	
	E27059	0.43	
W4	E27060	0.38	0.39
	E27061	0.40	
W5	E27062	0.29	0.30
	E27063	0.31	
	E27044	0.31	
W6	E27064	0.26	—
Mean maximum diameter for all specimens listed = 0.37			

Geographic distribution: Watton Cliff, Herbury Point (Bathonian deposits), and Redcliff (Oxfordian deposits), Dorset coast.

Discussion: All of the sclerites referred to *Frizzellus*, n. gen., have been assigned to a single broadly defined species, variations being interpreted as resulting from different developmental stages and differences in gross outline and ornamentation. The maximum diameter of *Frizzellus irregularis* varies between 0.26 mm. (E27045; E27046; and E27064) and 0.52 mm. (E27058) at least, and owing to the overall morphological similarity of the sclerites and their occurrence throughout the exposures studied, the species is considered coherent. Neither of the previously described specimens (Hampton, 1957, text-figs. 11–12) (E27043, pl. 1, fig. 16; E27044, pl. 1, fig. 21) is here selected as the holotype of *Frizzellus*



TEXT-FIGURE 1

Sections of the Bathonian stratigraphic column for the Dorset coastal exposures studied. Numbers preceded by the symbols F, H and W refer to samples collected in which *Frizzellus*, n. gen., occurred; the relative positions of the samples are approximate, as is the scale. The ammonite zone given is that quoted by Welch and Crookall (1948, p. 78) for contemporaneous deposits in Somerset, England.

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irregularis because of their small maximum diameters (0.35 mm. and 0.31 mm., respectively.) Two specimens (E27060, pl. 1, fig. 30; and E27063, pl. 1, fig. 20) exhibited more regular surface granulation, appearing identical to the " 'perforated' plate, type A" of Hodson, Harris and Lawson (1956, p. 343). They may represent a species distinct from *Frizzellus irregularis*.

Remarks: The specific name refers to the highly variable gross outline of *Frizzellus*, n. gen. Twenty-two specimens, excluding those in the collection of Frizzell and Exline, were available for study.

STATISTICAL APPENDIX

Introduction

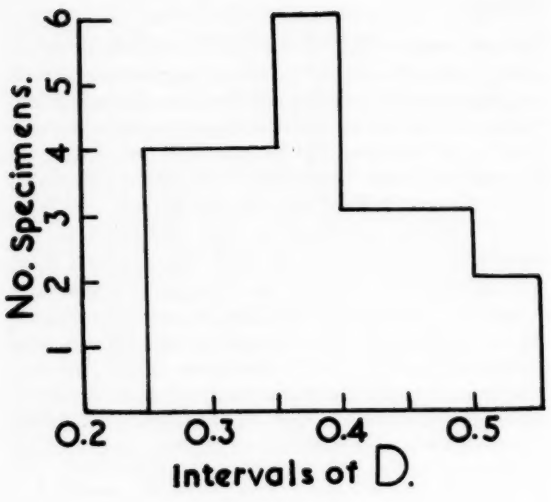
Certain applications of statistical methods to problems of quantitative paleontology have been described and discussed in considerable detail by Burma (1948, 1949), and in the field of micropaleontology several studies of continuous morphologic variation in foraminifera have been made (Wood and Barnard, 1946; Adams, 1957). The present author, however, could find no reference in the literature to the statistical analysis of numerical data derived from the examination of fossil holothurian sclerites, and it appears expedient, therefore, to consider *Frizzellus*, n. gen. (*qua* "parataxon"; see Moore and Sylvester-Bradley, 1957; Hampton, 1958), from a statistical standpoint to ascertain whether or not it represents a coherent unit of the zoological genus from which it was derived, within the sections and localities studied.

Statistical analysis

Basic assumptions: As the geologic sections studied at both localities are contemporaneous and therefore represent a certain continuous period within the Bathonian, the specimens examined were *combined* into a single *sample* for the purpose of statistical manipulation. Further, as all the sclerites exhibited a roughly circular to hexagonal outline, the *maximum diameter* (D) in mm. was considered to be the *numerical characteristic* of the sample and the *differentiating parameter* of *Frizzellus*, n. gen.

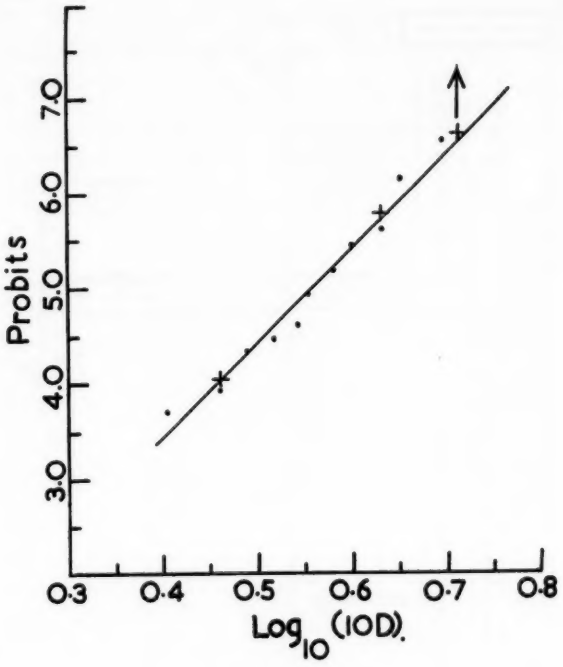
Methods: By constructing a *histogram* of the *distribution* of the differentiating parameter about its *mode*, a diagram (text-fig. 2) showing *unimodal positive skewness* was obtained. It is reasonable to assume that this phenomenon is also a characteristic of *Frizzellus* at the localities studied, and further, a normal distribution histogram may be obtained by plotting the *frequency* against $\log_{10}$D.

In any biospecies from which the sclerites of *Frizzellus* could have been derived, it would be expected to find sclerites in all stages of morphologic ontogeny, but in all except the most immature (juvenile) biospecies, a preponderance of fully formed sclerites would be expected, along with a comparatively small number of juvenile but rapidly developing sclerites. This situation is therefore reflected in the characteristic skew distribution of the sample. It is possible, however, that other factors could have given rise to such a phenomenon—for example, the nature of sedimentation at the time of deposition of



TEXT-FIGURE 2

Distribution of D over the interval range 0.20–0.55 mm., showing unimodal positive skewness (for explanation see text).



TEXT-FIGURE 3

Probit regression line for $\log_{10}(10D)$ of *Frizzellus*, n. gen. The arrow indicates 100% probit; • points for empirical probits; and + regression equation points for Y (data in Table 2; for explanation see text).

the sclerites on the sea floor may have been selective, and it should be noted that *non-selective techniques were applied in the picking of material for study.*

Assuming the most probable hypothesis, that the skew distribution represents the actual nature of the sclerite assemblage in the population of biospecies originally containing *Frizzellus*, a statistical method was employed to test the validity of the hypothesis that the sclerites, varied though they may be in size, actually form a coherent unit of a zoological genus as far as the generic concept (*qua* "parataxon"; see above) is concerned. From the standpoint of statistics the sample is small, but the results obtained fitted the hypothesis so well that it is considered worthwhile to record the procedure.

Although *probit analysis* is more particularly concerned with *quantal data* (see Finney, 1947), it appeared to be a convenient technique to apply in this case to transform the sigmoid curve of the distribution to a straight line. Table 2 shows the main calculations for fitting a probit regression line to D (Column 1), arranged in systematic form for routine computing. The columns have been numbered for ease of reference.

In Column 2, x is simply $\log_{10}$ of 10D taken in order to avoid negative logarithms, and Column 3 contains the number (n) of specimens for each value of D. Column 4 is the percentage (p) for increasing sub-total values of xn, so that $\frac{100 \, S x_i n_i}{(Sxn)} = pi$, where S denotes summation. The values for p were plotted against $\log_{10}$ (10D), and a sigmoid distribution curve was obtained; this curve was transformed by obtaining (from Transformation of Percentages to Probit tables; see Finney, 1947, p. 22, table 1) and plotting the *empirical probit* (Column 5) of p (text-fig. 3).

From this, an approximate linear relationship was apparent, and a straight line, the *provisional regression line*, was drawn by eye to fit the points as closely as possible. Column 6 contains the *expected probit* (Y), defined as being the ordinates of the provisional regression line corresponding to the value of x studied (Burn, Finney and Goodwin, 1950,

TABLE 2

COMPUTATIONS FOR FITTING THE PROBIT REGRESSION EQUATION

1	2	3	4	5	6	7	8	9	10
D	x	n	p	*Empirical probit*	Y	nw	y	nwx	nwy
0.26	0.415	3	10	3.72	3.5	0.81	3.76	0.33615	3.0456
0.29	0.462	1	14	3.92	4.0	0.45	3.92	0.20328	1.7248
0.31	0.491	3	26	4.36	4.3	1.60	4.36	0.78560	6.9760
0.33	0.519	1	30	4.48	4.6	0.60	4.48	0.31140	2.6880
0.35	0.544	1	35	4.61	4.8	0.63	4.62	0.34272	2.9106
0.36	0.556	3	48	4.95	5.0	1.91	4.95	1.05640	9.4050
0.38	0.580	2	58	5.20	5.2	1.25	5.20	0.72500	6.5000
0.40	0.602	2	67	5.44	5.4	1.20	5.44	0.72240	6.5280
0.43	0.633	1	73	5.61	5.7	0.53	5.61	0.33549	2.9733
0.45	0.653	3	88	6.18	5.9	1.41	6.14	0.91420	8.5960
0.50	0.699	1	94	6.55	6.4	0.30	6.54	0.20970	1.9620
0.52	0.716	1	100	∞	6.6	0.24	7.09	0.17184	1.7016

$Snw = 10.93$ $Snwx = 6.11418$ $Snwy = 55.0109$ $1/Snw = 0.091491$ $\bar{x} = 0.5594$ $\bar{y} = 5.0330$

$$\frac{Snwx^2}{Snw} = \frac{3.4889}{3.4230} \quad \frac{(Snwx)\ (Snwy)}{Snw} = \frac{31.4785}{30.7729} \quad \frac{Snwy^2}{Snw} = \frac{284.340}{276.872}$$

$S_{xx} = 0.0686$ $S_{xy} = 0.7056$ $S_{yy} = 7.468$

$\frac{(S_{xy})^2}{S_{xx}} = 7.253$

$\chi^2_{[10]} = 0.215\ (P > 0.99)$

$b = \frac{S_{xy}}{S_{xx}} = 10.28$

$Y = \bar{y} + b(x - \bar{x})$

D	Y
0.29	4.03
0.43	5.79
0.52	6.64

For explanation see text.

p. 122); the *probit weighting coefficients* (*nw*) (Column 7) for values of Y were obtained from appropriate tables (see Finney, 1947, p. 32, table 4). Column 8, of working probits (y), was obtained from tables (e.g., Finney, 1947, pp. 239–248, table 4), and Columns 9 and 10 (*nwx* and *nwy*, respectively) were obtained by arithmetical manipulation of the values concerned. From the data tabulated, a calculation of a *weighted regression equation* of y on x was shown to be an improved version of the *provisional regression line* (see above and text-fig. 3).

The totals *Snw*, *Snwx*, and *Snwy* were calculated and $\bar{x}$ obtained from the expression $\bar{x} = \frac{Snwx}{Snw}$, and $\bar{y}$ from $\bar{y} = \frac{Snwy}{Snw}$. The following manipulations were then made:

$$\frac{(Snwx)^2}{Snw}; \qquad \frac{(Snwx)\,(Snwy)}{Snw}; \quad \text{and} \quad \frac{(Snwy)^2}{Snw};$$

and their respective values entered as shown in Table 2. The values for $Snwx^2$, *Snwxy*, and $Snwy^2$ were calculated and entered. From the data,

$$Snwx^2 - \frac{(Snwx)^2}{Snw} = S_{xx}\,..\,(1); \quad Snwxy - \frac{(Snwx)\,(Snwy)}{Snw} = S_{xy}..\,(2); \text{ and } Snwy^2 - \frac{(Snwy)^2}{Snw} = S_{yy}\,..\,(3).$$

Now these values allowed the regression coefficient of y on x to be expressed by the formula $b = S_{xy}/S_{xx}$, the regression equation being therefore: $Y = \bar{y} + b\,(x-\bar{x})$. The values for Y at D = 0.29, 0.43, and 0.52 (see Table 2) were obtained and plotted as shown in text-figure 3; these points lie on the *calculated regression line*, which, as can be seen, is scarcely distinguishable from the *provisional regression line*.

The final step was to test the validity of the hypothesis that the individual values for D, on the $\log_{10}$ (10D) scale, are normally distributed and possibly form a coherent unit. This takes the form of a chi-square test, but is closely related to the *analysis of variance test* for examining the linearity of a regression:

Now $S_{yy} - \frac{(S_{xy})^2}{S_{xx}} = \chi^2$, with ten degrees of freedom (*d. f.* = number of D values minus 2).

Therefore $\chi^2_{[10]} = 0.215$ ($P > 0.99$).

A value for $\chi^2_{[10]}$ as great as 18.3 could occur by chance (0.05 probability), and thus there is no suspicion of *non-normality*, or *non-linearity* of the *probit regression line*.

CONCLUSION

From the *linearity test for* χ^2 ($P > 0.99$) given above, it is concluded that the sclerites of *Frizzellus*, n. gen.

PLATE 1

All specimens of *Frizzellus irregularis* Hampton, n. gen., n. sp. All figures × ca. 42 unless otherwise stated. See Table 1 and text-figure 1 for sample numbers, levels, and localities, unless given.

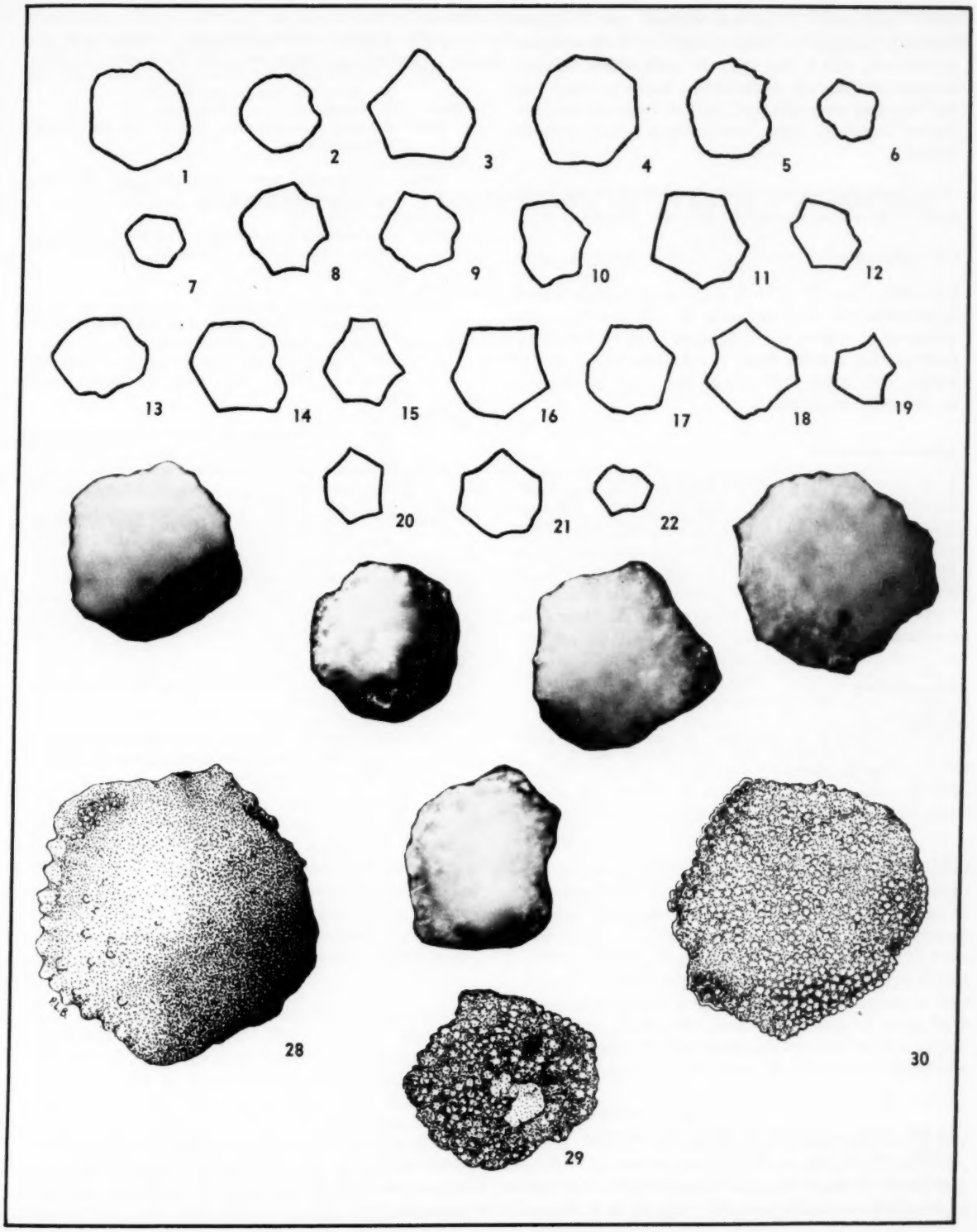
1–22 Diagrammatic camera-lucida drawings to show the approximate gross variation in the outline of the species: 1, holotype, E27056; 2–22, paratypes: 2, E27055; 3, E27057; 4, E27058; 5, E27059; 6, E27045; 7, E27046; 8, E27047; 9, E27048; 10, E27049; 11, E27050; 12, E27051; 13, E27052; 14, E27053; 15, E27054; 16, E27043 (× ca. 52); 17, E27060; 18, E27061; 19, E27062; 20, E27063; 21, E27044 (× ca. 52); 22, E27064.

23–27 Photomicrographs of specimens obtained from sample W3 (Watton Cliff), all × ca. 100: 23, holotype E27056; 24–27, paratypes: 24, E27055; 25, E27057; 26, E27058; 27, E27059.

28 Holotype, E27056, camera-lucida drawing, × ca. 127.

29 Camera-lucida drawing of a small specimen (E27045) from sample H1 (Herbury Point), × ca. 127.

30 Camera-lucida drawing of a plate (E27060) showing more regular surface granulations, similar to "'perforated' plate, type A" of Hodson, Harris and Lawson (1956); sample W4 (Watton Cliff); × ca. 127.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(*qua* "parataxon"), at the sections and localities studied, comprise a coherent unit of the zoological genus from which they were derived, which exhibits normal distribution. It should be borne in mind that the sclerites were selected on the basis of morphological similarity, size alone being a highly variable factor.

The *standard deviation* (σ), an indication of the variance of D about its mean ($\overline{D}$), was obtained from the expression $\sigma^2 = \frac{S(D-\overline{D})^2}{n-1}$. For *Frizzellus* $\sigma =$ 0.12 mm., but $\overline{D} \pm 3\sigma$ is the range within which approximately 99.7 per cent of all possible variations of D will occur. Therefore, any morphologically similar sclerite from the Bathonian having D within the range 0.37 ± 0.36 mm. can be referred to *Frizzellus irregularis*.

ACKNOWLEDGMENTS

I am indebted to Professor Don L. Frizzell, of the Missouri School of Mines and Metallurgy, for suggesting this study and for his helpful criticism during its preparation; to Dr. D. J. Bauer and Mr. P. L. Bradley, of the Wellcome Laboratories of Tropical Medicine, for assistance in preparing the Statistical Appendix; and to Miss Gwendolen A. Hayes for preparing text-figure 1.

BIBLIOGRAPHY

ADAMS, G. C.
1957 – *A study of the morphology and variation of some Upper Lias foraminifera.* Micropaleontology, vol. 3, no. 3, pp. 205–226.

BURMA, B. H.
1948 – *Studies in quantitative paleontology; 1–Some aspects of the theory and practice.* Jour. Pal., vol. 22, pp. 725–761.
1949 – *Studies in quantitative paleontology; 2–Multivariate analysis.* Jour. Pal., vol. 23, pp. 95–103.

BURN, J. H., FINNEY, D. J., AND GOODWIN, L. G.
1950 – *Biological standardization.* Ed. 2. London: Oxford University Press.

CHATWIN, C. P.
1948 – *The Hampshire Basin and adjoining areas.* Brit. Reg. Geol.; London: H.M.S.O.

DEFLANDRE-RIGAUD, M.
1952 – *Contribution à la systématique des sclérites d'holothurides fossiles.* Monaco, Inst. Océanogr., Bull., no. 1012, pp. 1–15.

FINNEY, D. J.
1947 – *Probit analysis: A statistical treatment of the sigmoid response curve.* Cambridge: University Press.

FRIZZELL, D. L., AND EXLINE, H.
1955 – *Monograph of fossil holothurian sclerites.* Missouri, Univ., School Mines and Met., Bull., no. 89, pp. 1–204, pls. 1–11.

HAMPTON, J. S.
1957 – *Some holothurian spicules from the Upper Bathonian of the Dorset coast.* Geol. Mag., vol. 94, no. 6, pp. 507–510.
1958 – *Comment on the Moore/Sylvester-Bradley "parataxa plan."* Bull. Zool. Nomencl., vol. 15, pt. 7/8, pp. 245–246.

HODSON, F., HARRIS, B., AND LAWSON, L.
1956 – *Holothurian spicules from the Oxford Clay of Redcliff, near Weymouth (Dorset).* Geol. Mag., vol. 93, no. 4, pp. 336–344.

MOORE, R. C., AND SYLVESTER-BRADLEY, P. C.
1957 – *Suggested new article: Proposed recognition of the concept "parataxon" and the provision of rules for the nomenclature of units of this category.* Bull. Zool. Nomencl., vol. 15, pt. 1/4, pp. 5–13.

WELCH, F. B. A., AND CROOKALL, R.
1948 – *Bristol and Gloucester District.* Brit. Reg. Geol.; London: H.M.S.O.

WOOD, A., AND BARNARD, T.
1946 – *Ophthalmidium: A study of nomenclature, variation and evolution in the foraminifera.* Geol. Soc. London, Quart. Jour., vol. 52, pp. 77–107.

Erratum

In the paper by John S. Hampton entitled "Subgenera of the holothurian genus *Achistrum*" (Micropaleontology, vol. 4, no. 1, pp. 75–77, January, 1958), the figure numbers on the text-figures were printed in an erroneous form, without the knowledge of the author. The numbers should be corrected as follows: 1a to 1; 1b to 2; 2a to 3; 2b to 4; 3a to 5; 3b to 6; 4a to 7; and 4b to 8.

ABSTRACT: *The first record of the genus* Hantkenina *in the Eocene of Western Australia is discussed. The species described are* Hantkenina (Applinella) *cf.* dumblei *Weinzierl and Applin and* Hantkenina (Applinella) *cf.* longispina *Cushman. Associated species of foraminifera indicate a Middle to Upper Eocene age.*

The occurrence of Hantkenina in Western Australia

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INTRODUCTION

The first record in Western Australia of the widely distributed Eocene genus *Hantkenina* was made recently during the examination of samples from Cape Range no. 1 bore, Carnarvon Basin, Western Australia, which was drilled by West Australian Petroleum Proprietary Limited in the search for oil in that region. The bore, which is situated on the northeast flank of the Cape Range Anticline between Exmouth Gulf and the Indian Ocean (Condon *et al.*, 1953), was drilled to a depth of 8019 feet. Microfossils of Lower Miocene ("*e*" stage), Middle to Upper Eocene ("*a–b*" stage), Paleocene, Upper Cretaceous (Campanian to Maestrichtian), and Lower Cretaceous (Neocomian to Albian) age were recognised in cores and cuttings at least down to the depth of 3550 feet and probably to the depth of 5115 feet. Beds of Jurassic age were determined below this depth, down to the bottom of the bore. Fourteen specimens of *Hantkenina* were found in a rather tough calcarenite between the depths of 850 feet and 870 feet, in association with a characteristic assemblage of small Eocene species of foraminifera and the larger Eocene genus *Discocyclina*.

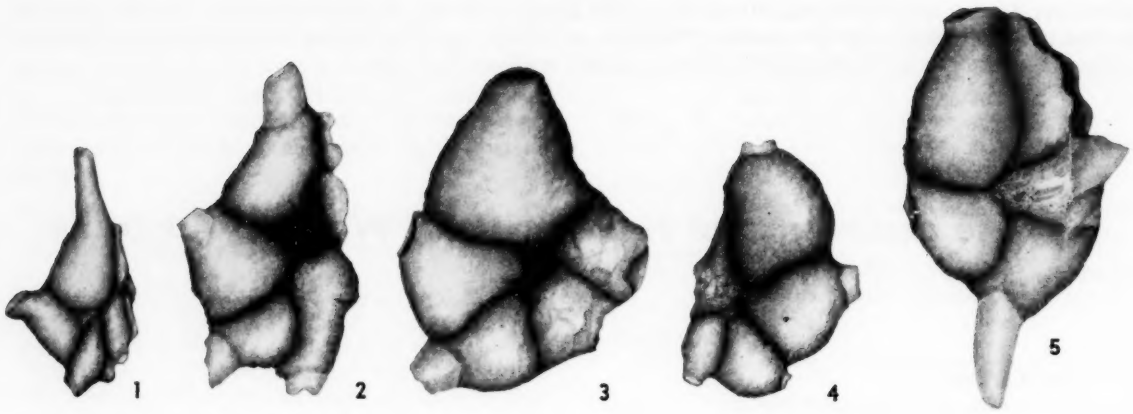
The first record of *Hantkenina* in the Australian Tertiaries was made by Parr (1947), when he discovered the genus at Brown's Creek, Otway area, Victoria, and at Hamilton Creek, 6 miles east of Brown's Creek. He named this form *Hantkenina alabamensis* Cushman subsp. *compressa* Parr. Later he found the species in the Blanche Point limestone of Maslin Beach, South Australia (Crespin, 1954). Crespin recorded it from the basal beds at Bird Rock, Torquay, Victoria (Crespin, 1952; Raggatt and Crespin, 1955). Some palaeontologists question whether or not the tests of *Hantkenina* are indigenous to these beds, suggesting that they may be derived or reworked and that the beds may be Lower Oligocene in age. Further detailed work on this section is necessary in order to substantiate this view.

Parr (1937) also made the first record of *Hantkenina* in the Pacific region, when he discovered the genus in deposits near Auckland, New Zealand. Thalmann (1942*b*) found several species of the genus at localities in East Borneo, and concluded that the beds range in age from late Lower Eocene to middle Upper Eocene. Hanzawa (1957) reports *Hantkenina* from the island of Rota, Marianna Islands, and Todd (1957) reports it from Saipan, in the same group.

Bronnimann (1950) has suggested that Parr's (1947) text-figures 5, 6, 7 and 7a of *Hantkenina alabamensis* subsp. *compressa* fall within the natural range of variation of *Hantkenina alabamensis*. Bronnimann (1950) further commented that Parr's (1947) text-figures 1 and 2 represent *Hantkenina primitiva* Cushman and Jarvis, and that Parr's text-figure 4 may represent *Hantkenina liebusi* Shokhina or may be a young stage of *Hantkenina alabamensis* with a primitive arrangement of spines in the early chambers.

NOTES ON THE SPECIMENS

None of the fourteen specimens of *Hantkenina* found in the Cape Range no. 1 bore is complete. However, characteristic features suggest that at least two species are present. These species are referred to



TEXT-FIGURES 1–5

1–4, *Hantkenina* (*Applinella*) cf. *dumblei* Weinzierl and Applin, × 100; 5, *Hantkenina* (*Applinella*) cf. *longispina* Cushman, × 100.

Hantkenina (*Applinella*) cf. *dumblei* Weinzierl and Applin and *Hantkenina* (*Applinella*) cf. *longispina* Cushman. The best available specimens are figured.

Hantkenina (*Applinella*) cf. *dumblei* (Commonwealth Palaeontological Collection, nos. 1525–1528) is represented by text-figures 1–4. The tests are composed of four or five chambers, which are slightly lobulate and increase rapidly in size, the last-formed chamber being much larger than the preceding one and typically triangular in shape. The sutures are strongly depressed and straight or slightly curved. The umbilicus is open. The spines, all of which are broken, are situated at the anterior angles of the chambers, immediately below the sutures, and the angle of projection of the spines is almost parallel to the direction of the sutures. The apertural chamber in all tests is broken. Maximum diameter of test, excluding spines: Specimen no. 1, 0.22 mm.; specimen no. 2, 0.42 mm.; specimen no. 3, 0.50 mm.; specimen no. 4, 0.40 mm. The figured specimens resemble those figured by Bronnimann (1950) as *Hantkenina* (*Applinella*) *dumblei* (pl. 55, figs. 18, 22–24) and *Hantkenina* (*Applinella*) cf. *dumblei* (pl. 56, fig. 5).

Hantkenina (*Applinella*) cf. *longispina* (C.P.C. no. 1529) is shown in text-figure 5. The test, though broken, is subelliptical in outline, the last chamber tending to become lobulate. Only three complete chambers are present. The second chamber is slightly larger than the first; the third chamber is about twice the size of the second, and is slightly inflated. The sutures are straight except for one that is slightly curved possibly owing to slight distortion of the test. A strong spine protrudes from immediately below the suture between the first and second chambers. Indications are that the other two broken spines were equally strong. The apertural chamber is broken. Maximum diameter of test, excluding spines, 0.48 mm. The one very stout spine present in this specimen seems to leave little doubt that the species closely resembles *Hantkenina* (*Applinella*) *longispina*.

ASSOCIATED FORAMINIFERA AND AGE OF THE BEDS

The assemblage of foraminiferal species associated with *Hantkenina* in the Cape Range material contains abundant small forms in which tests of planktonic species predominate. Small tests of *Discocyclina* were also noted. The assemblage includes the following species:

Ammolagena clavata (Parker and Jones)
Ammodiscus parri Crespin
Angulogerina subangularis Parr
Bathysiphon angleseaensis Crespin
Bolivinopsis crespinae Parr
Cyclammina incisa (Stache)
Cyclammina rotundata Chapman and Crespin
Fissurina terrilli (Parr)
Gaudryina (*Pseudogaudryina*) *jacksonensis* Cushman
Globigerina finlayi Bronnimann
Globigerina mexicana Cushman
Globigerina taroubensis Bronnimann

Globigerina triloculinoides Plummer
"*Globigerinella*" *micra* (Cole)
Globorotalia crassata Cushman
Guembelina venezuelana Nuttall var. *rugosa* Parr
Lagena perthensis Parr
Vulvulina advena Cushman

Amongst the planktonic species, *Globorotalia crassata* is typical of the upper Middle Eocene sediments of both the Middle East and the Gulf of Mexico–Caribbean area (Grimsdale, 1951). "*Globigerinella*" *micra* ranges from Lower to Upper Eocene. Other species, such as *Angulogerina subangularis*, *Bolivinopsis crespinae*, *Fissurina terrilli*, *Lagena perthensis*, and *Guembelina venezuelana* var. *rugosa*, were described by Parr (1938) from the Upper Eocene of the King's Park bore, Perth, Western Australia.

Both *Hantkenina* (*Applinella*) *dumblei* and *Hantkenina* (*Applinella*) *longispina* range from Lower to Middle Eocene, with rare occurrences in the Upper Eocene. However, with the present available evidence, the beds containing *Hantkenina* in the Cape Range Bore are considered to be Middle to Upper Eocene in age.

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BIBLIOGRAPHY

BRONNIMANN, P.
1950 – *The genus Hantkenina Cushman in Trinidad and Barbados, B.W.I.* Jour. Pal., vol. 24, no. 4, pp. 397–420.

CONDON, M. A., JOHNSTONE, D., PERRY, W. J., AND CRESPIN, I.
1953 – *The Cape Range structure, Western Australia.* Australia, Bur. Min. Res., Bull., no. 21.

CONDON, M. A., JOHNSTONE, D., PRITCHARD, C. E., AND JOHNSTONE, M. H.
1956 – *The Giralia and Marilla Anticlines, North West Division, Western Australia.* Ibid., Bull., no. 25.

CRESPIN, I.
1952 – *Occurrence of Hantkenina at Torquay, Australia, and the age of the "Janjukian" and "Anglesean" stages.* Cushman Found. Foram. Res., Contr., vol. 3, no. 3–4, p. 144.
1954 – *Stratigraphy and micropalaeontology of the marine Tertiary rocks between Adelaide and Aldinga, South Australia.* Australia, Bur. Min. Res., Rept., no. 12.
1956 – *Migration of foraminifera in Tertiary times in Australia.* Ibid., no. 25, pp. 2–15.

FINLAY, H. J.
1939 – *New Zealand foraminifera: The occurrence of Rzehakina, Hantkenina, Rotaliatina and Zeauvigerina.* Roy. Soc. New Zealand, Trans., vol. 68, pt. 4, pp. 534–543.
1947 – *The foraminiferal evidence for Tertiary trans-Tasman correlation.* Ibid., vol. 76, pt. 3, pp. 327–352.

GRIMSDALE, T. F.
1951 – *Correlation, age determination, and the Tertiary pelagic foraminifera.* World Petr. Congress, Third, Proc., Sect. 1, pp. 463–475.

HANZAWA, S.
1957 – *Cenozoic foraminifera of Micronesia.* Geol. Soc. Amer., Mem., no. 66.

HOWE, H. V.
1928 – *An observation on the range of the genus Hantkenina.* Jour. Pal., vol. 2, pp. 13–14.

PARR, W. J.
1937 – *Tertiary foraminifera from near Bombay, Franklin County, Auckland, New Zealand.* Roy. Soc. New Zealand, Trans., vol. 67, pp. 71–77.
1938 – *Upper Eocene foraminifera from deep bores in King's Park, Western Australia.* Roy. Soc. Western Australia, Jour., vol. 24, pp. 69–101.
1947 – *An Australian record of the foraminiferal genus Hantkenina.* Roy. Soc. Victoria, Proc., new ser., vol. 58, pp. 45–47.

RAGGATT, H. G., AND CRESPIN, I.
1955 – *Stratigraphy of Tertiary rocks between Torquay and Eastern View, Victoria.* Ibid., new ser., vol. 67, pt. 1, pp. 76–142.

THALMANN, H. E.
1932 – *Die Foraminiferen-Gattung Hantkenina Cushman 1924 und ihre regional-stratigraphische Verbreitung.* Eclogae Geol. Helv., vol. 25, pp. 287–292.
1942*a* *Foraminiferal genus Hantkenina and its subgenera.* Amer. Jour. Sci., vol. 240, pp. 809–820.
1942*b* *Hantkenina in the Eocene of East Borneo.* Stanford Univ., Publ., Geol. Sci., vol. 3, no. 1, pp. 5–24.

TODD, R.
1957 – *Smaller foraminifera.* In: *Geology of Saipan, Mariana Islands; Part 3 – Paleontology.* U. S. Geol. Survey, Prof. Paper, no. 280-H, pp. 265–320.

ABSTRACT: *Sporomorph assemblages found in the Keuper section of the borehole Swierczyna no. 1 were examined. Their stratigraphic positions and relationships to climatic conditions are discussed. Nine new forms are described.*

Keuper sporomorphs from Swierczyna, Poland

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INTRODUCTION

The first pollen analyses of Mesozoic deposits in Poland were carried out by Rogalska. She investigated the Liassic brown coal deposits of Zawiercie, in Katowice vojevudstvo (1954), and the Liassic sediments of the Mroczków-Rozwady area, in Opoczno poviat (1956). Both papers cover pollen assemblages in which forms diagnostic of the Lias α prevail.

In 1955, the Central Laboratory of the Petroleum Industry, in Krakow, began a study of the pollen-bearing Mesozoic deposits of the Pomerania-Kujawy uplift. The pollen profiles of the boreholes Złotów no. 1 (by Zofia Kita) and Swierczyna no. 1 (by Maria Pautsch and Anna Szwabowicz) were examined in detail and correlated with the Dębniewice and Jeziorna boreholes. All of these boreholes are in Koszalin vojevudstvo, Złotów no. 1 in Złotów poviat, Swierczyna no. 1 and Dębniewice in Drawsko poviat, and Jeziorno in Szczecinek poviat.

All of these boreholes reveal the existence of a thick sequence containing sporomorphs diagnostic of the Lias α, but the deepest borehole, Swierczyna no. 1, also penetrated the Rhaetic and Keuper below the Lias α. The beds correlated with the Rhaetic by the petroleum geologists contain an assemblage of sporomorphs that is very different from the Lias α assemblages mentioned above. In addition, the beds correlated by the geologists with the Keuper contain three new assemblages. The present paper deals specifically with the latter three assemblages. They deserve particular attention because the majority of forms included in them are new and have not previously been described.

STRATIGRAPHIC POSITION OF THE SPOROMORPHS

The eighty-six Keuper samples from the Swierczyna no. 1 borehole analyzed by the present author were recovered from a depth of 647–791 meters. A new method developed by the present author (Pautsch, 1957) was used in maceration. After crushing, the samples were treated first with hydrochloric acid to remove carbonates, then with hydrofluoric acid to dissolve silicates, and finally with Griczuk heavy liquid to concentrate the organic material. Griczuk's liquid consists of 9 parts of potassium iodide to 10 parts of cadmium iodide in water acidulated with hydriodic acid. If it was found that sporomorphs were still clinging to the carbonized organic residue, then maceration was continued according to Thiergart's method (Thiergart, 1940).

In the following section I have followed the sample description given by Stemulak (MS.) in indicating the lithology:

647–668 Red and green shales. No sporomorphs. The shales are probably of desert origin. The absence of sporomorphs is easily explained by the fact that, under desert conditions, organic material decomposes completely.

668–674 No core.

674–685 Gray shales. Great variety of sporomorphs:

- 52% *Picea-Pollenites fuscus* n. sp.
- 19% *Caytoniales-Pollenites diaphanus* n. sp.
- 12% Filicinae; this is the largest percentage of spores of Filicinae in the Keuper of Swierczyna no. 1.
- 6% *Ovalipollis* Krutzsch (pl. 1, fig. 3).
- 2% Pollen of the type of *Saccopollis parvo-saccata* Pflug (pl. 1, fig. 14).
- 2% *Pinus haploxylon* Rudolph.
- 1.5% Cycadinae.
- 1% *Sporites telephorus* n. sp.

The presence of spores with a sculpture of parallel rings characterizes the sediments at 674–677 meters. Sporo-

morphs such as *Lepidodendron* and *Nuphar* sp. were found in amounts less than 1% at 675–679 meters. The occurrence of *Lepidodendron* and *Nuphar* together with the maximum occurrence of Filicinae spores indicates a probable humid environment and shallow water.

685–692 Red and green shales. No sporomorphs.

692–709 Gray shales containing an assemblage somewhat similar to the previous one, although pollen of the type of *Ovalipollis* Krutzsch is absent, and the percentage of individual sporomorphs is different.

- 79% *Caytoniales-Pollenites diaphanus* n. sp.
- 7% *Caytoniales?-Pollenites fuscocorpus* n. sp.
- 12% *Picea-Pollenites fuscus* n. sp.
- 2% *Sporites telephorus* n. sp. Spine-bearing spores.
- 1% Pollen of the type of *Saccopollis parvosaccata* Pflug (pl. 1, fig. 14).

Tiny sporomorphs (20–30 microns) that are greatly crumpled, so that the original form is difficult to reconstruct, occur in both of the gray shale assemblages described above, but have not been included in the percentual evaluation. Some of them are smooth, sometimes showing the outlines of three pores, and resemble *Tricolpites troedssoni* Erdtman. Others have a form and sculpture similar to *Classopollis* Pflug. A third group of sporomorphs have a structure that appears to be triangular in form and with spine-like prominences in the equatorial zone. We were unable to establish the relationships and percentage values of the three groups of sporomorphs. It is possible that this problem will be solved after the final examination of better-preserved material of the same age that may be found in other boreholes in the vicinity.

709–715 Sandstones. No sporomorphs.

715–726 Red and green shales. No sporomorphs.

726–791 Gray shales of various shades interbedded with gypsum and anhydrite. Pollen is found in only two restricted zones (765–770 and 775–777 meters), but here it is very abundant. The forms are very different from those found in the 674–709 interval.

- 34% Cycadinae. Characteristic of these two zones. Their appearance is very uniform. The size is about 40μ, the outline is subround or rounded oval (pl. 1, fig. 15).
- 27% *Ovalipollis* Krutzsch (pl. 1, fig. 3).
- 5% *Pollenites sulcatus* n. sp.
- 6% *Picea?-Pollenites ferrugineus* n. sp.
- 3% *Sporopollenites zonalis* n. sp.
- 2% *Picea?-Pollenites aurentius* n. sp.
- 1% cf. *Podocarpus*.
- 1% cf. *Walchia*, highly variable in form (pl. 1, fig. 7).

The Caytoniales sporomorph is very rare. *Picea-Pollenites fuscus* n. sp. is absent. For the sake of completeness it must be mentioned that the sporomorphs of such rare genera as *Leptostrobus*, *Cordaites*, and cf. *Striatopinipites* Zoricheva and Sedova (pl. 1, fig. 9) occur sporadically.

The sequence of Keuper sporomorphs in Swierczyna no. 1 presented above suggests that the flora was undergoing a distinct change simultaneously with the desiccation of the marine basin, which ultimately became a desert, as is indicated also by the red shales. Red shales are believed to be deposits of the desert (Gignoux, 1955). It can therefore be assumed that the extinction of the flora of the 765–777 meter interval was caused by climatic changes, which culminated in a dry, hot desert at the time of deposition of the first red shales.

The assemblages occurring in the 674–685 and 692–709 intervals are found in the gray shales above the sandstone which in turn overlies the first group of red and green shales. The gray shales are interrupted by an intercalation of red and green shales, and in turn are terminated at the top by a thick layer of red and green shales. It must be assumed that these gray shales were deposited during periods of temporary humidification of the climate which interrupted the deposition of red and green shales produced under desert conditions. The temporary humidification of the desert appears to have ended at the 668-meter level. Pollen assemblages containing Caytoniales are absent above this horizon. The great thickness of red and green shales found above 668 meters indicates the final period of desert conditions. The gray shale flora did not survive this period.

The deposits identified as Keuper terminate at 647 meters, at the top of the thick red and green shale sequence. The deposits above this horizon contain an entirely different sporomorph assemblage.

The sporomorph assemblages found in the sediments identified as Rhaetic (542.2–647 meters) consist predominantly of tetradic forms, while the sporomorphs occurring in the 216–542 meter sequence of beds are diagnostic of the Lias α. Both the Rhaetic and the Lias α sporomorphs are being studied by Anna Szwabowicz.

Palynological examination of the entire area covered by this study is in progress. The program, in part already executed, will ultimately also include the extension of these studies to the entire area now covered by exploratory drilling for petroleum.

DESCRIPTION OF NEW FORMS

GYMNOSPERMAE

CAYTONIALES

Caytoniales-Pollenites diaphanus Pautsch, **new species**
Plate 1, figures 4, 11

Body thin-walled, translucent. Base of bladders slightly concave, so that they somewhat enclose the body. Often a third bladder or the rudiment of a third bladder is developed. Sculpture of bladders reticulate. Lumina almost spherical. Pollen of silvery straw color. Size 35–46μ. Similar sporomorphs but with a smaller body have been described by Harris (1932) as pollen grains of Caytoniales (*Caytonianthus* sp. div., *Sagenopteris* sp. div.).

Caytoniales?-Pollenites fuscocorpus Pautsch, **new species**
Plate 1, figure 5

Body smooth, dark colored. Bladders reticulate, with nearly spherical lumina. Size of pollen 36–52μ.

CONIFERAE

Picea-Pollenites fuscus Pautsch, **new species**
Plate 1, figure 1

Pollen dark brown, with only poorly developed bladders in equatorial view. In polar view a narrow slit is clearly visible between the bladders. Secondary folds are frequent. Size varies between 60 and 90μ.

Picea?-Pollenites aurentius Pautsch, **new species**
Plate 1, figure 6

Base of bladders completely invisible. Bladders distinguished from body only by their different sculpture. Along the margins of the body, between the outlines of the bladders in polar view, there are areas with a considerably thinner membrane. In specimens strongly secondarily flattened, this part of the membrane is broken. Pollen of a light straw color. Size from 172 to 240μ.

Picea?-Pollenites ferrugineus Pautsch, **new species**
Plate 1, figure 10

Body usually with secondary depressions. Bladders large and distinctly finely sculptured, of a red-brown color. Size 96–164μ.

SPORITES INCERTAE SEDIS

Sporites telephorus Pautsch, **new species**
Plate 1, figure 12

Spherical tetrahedral spore with spinous processes. Processes are conical, obtuse, up to 1.5μ long, sparingly distributed over the spore. Color golden brown. Size 30–40μ.

POLLENITES INCERTAE SEDIS

Pollenites sulcatus Pautsch, **new species**
Plate 1, figure 8

Body deeply grooved longitudinally on dorsal side. Two to four grooves have been observed. Bladders large, nearly hemispherical, rigid, with indistinct fine sculpture. Base of bladder straight. Color very dark; membrane thick. Some specimens are nearly opaque. Size varies from 92 to 114μ.

PROBLEMATICA

Sporopollenites zonalis var. **lenticulatus** Pautsch, **new species, new variety**
Plate 1, figure 2

Body lenticular, with a broad, strongly folded fringe. Sculpture of body and fringe reticulate. Reticule walls irregularly callous, with distinct protuberances. The whole gives the impression of an irregularly granulated surface. Tetrad marks have not been observed. Color golden to golden-brown. Size 52–96μ.

Sporopollenites zonalis var. **triangulus** Pautsch, **new species, new variety**
Plate 1, figure 13

These sporomorphs are very similar to those described above as *Sporopollenites zonalis* var. *lenticulatus*. In contrast to the latter, they have a triangular body with a dispersal apparatus consisting of three lobe-like elements. The sculpture, which is the same as in the foregoing form, is uniform in all portions of the sporomorph. The color of the body is usually slightly darker than that of the dispersal apparatus. Size same as that of the form described above.

ACKNOWLEDGMENTS

The author wishes to thank Dr. Eugene Jablonski for his kind assistance in translating the present paper from Polish into English.

BIBLIOGRAPHY

GIGNOUX, M.
1955 – *Stratigraphic geology.* San Francisco, Calif.: W. H. Freeman.

HARRIS, R. M.
1932 – *The fossil flora of Scoresby Sound, East Greenland.* Meddel. om Grønland, vol. 85, no. 5.

PAUTSCH, M.
1957 – *Methods of maceration of Mesophytic and Kenophytic forms for pollen analysis.* [Polish.] Wiad. Bot., Krakow, vol. 1, pt. 1–2.

ROGALSKA, M.
1954 – *Spore and pollen analysis of the Liassic coal of Blanowice in Upper Silesia.* Wyd. Geol. Biul., Warsaw, no. 89.
1956 – *Spore and pollen analysis of the Liassic deposits of the Mroczków-Rozwady area in the Opoczno district.* Wyd. Geol. Biul., no. 104.

STEMULAK, J.
[MS.] *Geological description of the borehole Swierczyna 1.* [Polish.] (Manuscript in the archives of the Geological Service of the Petroleum Industry, Krakow; 1955.)

THIERGART, F.
1940 – *Die Mikropaläontologie als Pollenanalyse im Dienst der Braunkohlenforschung.* Brennstoff-Geologie, no. 13.

PLATE 1

1 *Picea-Pollenites fuscus* Pautsch, n. sp.; 88μ.

2 *Sporopollenites zonalis* var. *lenticulatus* Pautsch, n. sp., n. var.; 96μ.

3 *Ovalipollis ovalis* Krutzsch; 96μ.

4 *Caytoniales-Pollenites diaphanus* Pautsch, n. sp.; 43μ.

5 *Caytoniales?-Pollenites fuscocorpus* Pautsch, n. sp.; 44μ.

6 *Picea?-Pollenites aurentius* Pautsch, n. sp.; 180μ.

7 cf. *Walchia* sp.; 128μ.

8 *Pollenites sulcatus* Pautsch, n. sp.; 108μ.

9 cf. *Striatopinipites* Zoricheva and Sedova; 58μ.

10 *Picea?-Pollenites ferrugineus* Pautsch, n. sp.; 120μ.

11 *Caytoniales-Pollenites diaphanus* Pautsch, n. sp.; 42μ.

12 *Sporites telephorus* Pautsch, n. sp.; 38μ.

13 *Sporopollenites zonalis* var. *triangulus* Pautsch, n. sp., n. var.; 84μ.

14 cf. *Saccopollis parvosaccata* Pflug; 58μ.

15 cf. *Cycas* sp.; 45μ.

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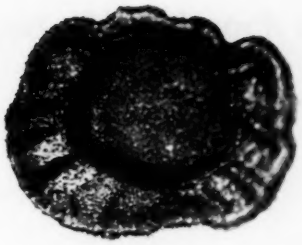
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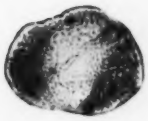
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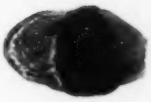
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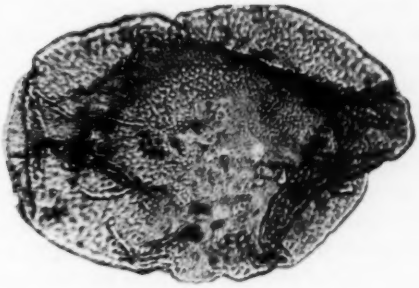
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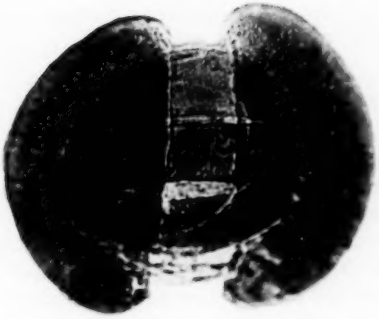
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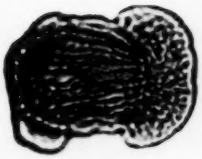
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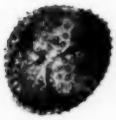
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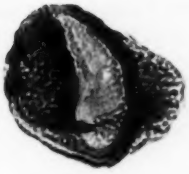
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A new method of hard-rock maceration

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Microfossils are usually separated from the matrix rock by means of maceration, in which warm or cold water, hydrogen peroxide, gasoline, a solution of Glauber's salt, or freezing water are used. In our laboratory, water, hydrogen peroxide or Glauber's salt is used. Early in our experience we followed Wicher's (1942) method, which consists of heating the dried sample in an aluminum dish on an asbestos mat over a Bunsen burner and then boiling the sample in a concentrated solution of Glauber's salt. This method, however, proved harmful to the microfossils, especially to the calcareous forms.

For the past several years we have been using a new procedure. The samples are first cleaned and crushed, and are then dried at a constant temperature, which may he as high as 90° C. Enough time is allowed for the samples to warm up and expand, after which hot concentrated Glauber's salt solution is poured over the sample and kept hot long enough for the samples to become thoroughly saturated and for the solution to penetrate sufficiently deeply into the rock.

After the sample becomes saturated, the excess solution is decanted off, and the dish is put in a cool place to permit crystallization. The period of crystallization has been reduced to one week or in some cases to a few days. The process of crystallization is considered complete when the sample looks dry and is covered with crystals of Glauber's salt. The sample is then treated with hot water, in which it is left for one or two days. After this the sample is usually ready for washing and screening.

The method described above has in general been adequate for the rocks of the Miocene and the Carpathian Flysch. It has not produced satisfactory results with the hard rocks of the Paleozoic and Mesozoic of the Polish Lowland. For these rocks we have developed a new method, which is also based on the pressures produced by the crystallization of Glauber's salt.

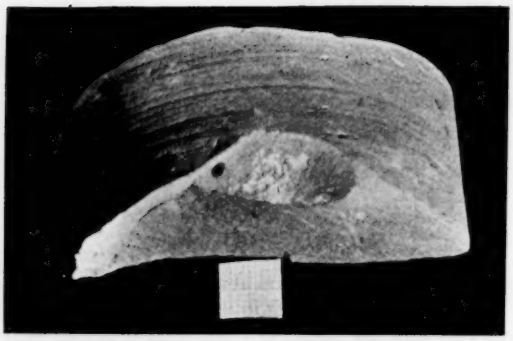
The *uncrushed* rock sample, in an enameled dish, is placed in the constant-temperature chamber and kept there for 1 to 2 hours at a temperature of 90° C. The sample is then removed from the chamber, covered with dry Glauber's salt, and replaced in the chamber. When the salt has fused, the sample is again removed, and the liquid Glauber's salt that has run to the bottom of the dish is collected and used in "icing" the surface of the sample so as to cover it completely. The sample, thus coated, is left in the constant-temperature chamber for another 30 minutes. It is then removed and carefully washed under cold running water directly under the faucet and then set aside to permit crystallization, which progresses rapidly. The next day the sample is completely covered with small crystals of Glauber's salt, and the surface of the sample shows numerous cracks and fissures. In the case of very hard and only slightly porous rocks, such as dolomites, marbles, and metamorphic quartzites, the procedure described must be repeated every day for 2 to 5 days. After this period, further treatment usually produces no results. After crystallization the sample is treated with boiling water and then washed and screened.

The value of the method of maceration described above lies in the number of microfossils recovered. The yield is more than three times as great as was obtained with the former method.

I wish to express my thanks to Józef Bajer, our laboratory assistant, who with great effort, willingness, and creative imagination has cooperated in developing this method. The author also wishes to thank Dr. Eugene Jablonski for his kind assistance in translating the present paper from Polish into English. This note is published with the permission of the Director of the Central Laboratory of the Petroleum Industry.

REFERENCE

WICHER, C. A.
1942 – *Praktikum der angewandten Mikropaläontologie.* Berlin: Borntraeger, 143 pp., 28 pls., 15 text-figs.



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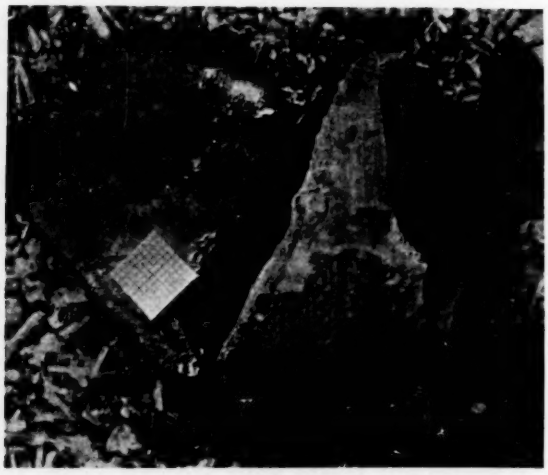
TEXT-FIGURE 1

Core fragment; hard argillaceous limestone, Cretaceous.



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TEXT-FIGURE 2

Two core fragments of the same type, after the crystallization of Glauber's salt according to the former method.

3

TEXT-FIGURE 3

Two core fragments after the crystallization of Glauber's salt according to the new method.

ABSTRACT: *The development of the series* Bolivinoides strigillata – decorata – australis – gigantea *in the Upper Cretaceous of Belgium is followed. In a nearly continuous sequence of formations, the group is found to increase the number of pustules on the last-formed sutures from two to nine. This continuous increase can be used as a stratigraphic tool in working out chronology from the lower Campanian to the uppermost Maestrichtian in northwestern Europe. In other areas where the same sequence of species, or parts of the sequence, are found, it can be applied in stratigraphy in the same manner.*

Upper Cretaceous Bolivinoides guide forms

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In 1950, Hiltermann and Koch published their first analysis of *Bolivinoides*. Because, however, many species of *Bolivinoides* are found in northwestern Germany, it was not possible to work out a good developmental series for any of the groups which they encountered. In Belgium, *Bolivinoides* is found to have developed in a single group. The series began in the lower Campanian with *Bolivinoides strigillata* (Chapman), which subsequently evolved into *Bolivinoides decorata* (Jones). The latter species first occurs as small, primitive forms, but later on, in the upper Campanian, it occurs in the form described by Jones. In Belgium a more or less extensive gap in the sedimentation is always found between the Campanian and the Maestrichtian. Where this gap is only a small one, as in the neighborhood of Mons, *Bolivinoides decorata* (Jones) is found to have developed very gradually into a more advanced form, *Bolivinoides australis* Edgell. During the Maestrichtian, the latter form developed gradually into the most advanced form of the group, *Bolivinoides gigantea* Hiltermann and Koch, in which all the pustules on the sutures were fused to form oblique longitudinal costae. Only those forms in which no separate pustules, or almost none, are found on the initial portion of the test should be included in *Bolivinoides gigantea*, as the type of that species (Hiltermann and Koch, 1950, p. 624, text-fig. 50) does not show any separate pustules.

As a basis for separating the species (or subspecies) *Bolivinoides strigillata*, *Bolivinoides decorata*, and *Bolivinoides gigantea*, Hiltermann and Koch give elaborate indices, which have the disadvantage that they are difficult to obtain and do not, in all cases, produce usable distinctions between the forms. It is much simpler to use another character, the number of pustules on the sutures of the last-formed chambers in adult specimens, extending throughout the sequence of forms from the upper Santonian to the uppermost Maestrichtian. In reality we find that, in the course of the development of the group of *Bolivinoides strigillata – decorata – australis – gigantea*, the angle of inclination of the last-formed sutures became more and more oblique, and consequently the possibility of developing more pustules along the sutures increased. I have already mentioned this continuous change in the number of pustules in this sequence of *Bolivinoides* species in another paper (Hofker, 1957), but I did not describe it fully at that time. I now propose to give an account of this development during the Campanian and Maestrichtian, on the basis of outcrops in Belgium whose geologic age has been determined by means of belemnites.

In the Craie de Saint Vaast near Mons, only *Bolivinoides strigillata* is found, associated with *Actinocamax quadratus*; the fauna as a whole indicates a lower Campanian age. In the Craie de Trivières, the simplest forms of *Bolivinoides decorata* are found; the Craie de Trivières is believed to be middle Campanian, on the basis of the macrofossils. *Bolivinoides strigillata* always shows two pustules on the last-formed sutures, whereas the most primitive forms of *Bolivinoides decorata* always show three of them (see pl. 1, figs. 1–4).

In the Craie d'Obourg near Mons, which contains *Belemnitella mucronata* and is upper Campanian, *Bolivinoides decorata* in the upper beds shows four pustules, but in the lower beds it shows only three (pl. 1, figs. 5–7). In the Craie de Nouvelles, the type found at the top of the Craie d'Obourg continues, but the Craie de Nouvelles is also upper Campanian (pl. 1, figs. 8–10).

Above these beds there is a gap in sedimentation, separating the Campanian from the Maestrichtian. This gap is very small in the neighborhood of Mons, and the overlying formation, the Craie de Spiennes, is lowermost Maestrichtian, as it contains *Belemnella lanceolata lanceolata*. Here, there are five pustules on the last-formed sutures (pl. 1, figs. 11–14). I classify this type as *Bolivinoides australis* Edgell. The form gradually becomes stouter, indicating a transition toward the stout form known as *Bolivinoides gigantea*.

Near Mons a large gap in sedimentation occurs between the lowermost Maestrichtian and the upper Maestrichtian, so that it is necessary to look elsewhere in Belgium for the upper lower Maestrichtian. These beds have been found just above Calembert's (1957) "hard ground" in a quarry at Hallembaye, in northeastern Belgium, where, in the lowermost meters, a formation was found containing belemnites that indicate a transition from the lower Maestrichtian into the lowermost upper Maestrichtian (*Belemnella lanceolata* and *Belemnitella junior*). Here, the pustules of *Bolivinoides* begin to lengthen and fuse, although large areas of the test remain covered with separate pustules. Moreover, the number of pustules on the last-formed sutures is six (pl. 1, figs. 15–16).

In the lower part of the Craie grise at Hallembaye, lengthening of the fusing pustules continues, and their number is six or seven. At this stage we are already in the lower part of the upper Maestrichtian, with *Belemnitella junior*. In the overlying Craie tigre, characterized by regular beds with chert nodules, *Bolivinoides australis* reaches its utmost development, gradually changing toward *Bolivinoides gigantea*, although that stage of development is not reached at the top of the quarry at Hallembaye because the uppermost Maestrichtian is not present there. Plate 1, figure 17, and plate 2, figure 18, show specimens from the Craie grise; plate 2, figures 19–21, show specimens from the Craie tigre. Both of these formations are lower upper Maestrichtian (*Belemnitella junior* zone).

The developmental series can be followed still further in the neighborhood of Mons, in southwestern Belgium. The Craie phosphatée de Ciply also belongs to the zone of *Belemnitella junior* and contains specimens of *Bolivinoides australis* in its most advanced form. This indicates that the Craie tigre and the Craie phosphatée must be almost identical in age (pl. 2, figs. 22–23).

The Craie phosphatée is overlain by the Tuffeau de Saint Symphorien. In the basal portion of that formation (but never in the higher layers), distinctly developed specimens of *Bolivinoides gigantea* are found, showing seven to nine pustules on the last-formed sutures, which extend the entire length of the test (pl. 2, fig. 24). A similar development is found in the Craie tuffoide in northeastern Belgium, where *Bolivinoides gigantea* is found, again only at the base of the formation, and likewise with seven to nine pustules covering the whole test (pl. 2, figs. 25–27).

In plates 1 and 2 the number of pustules on the last-formed sutures is indicated by Roman numerals above the tests. These numerals show a continuous increase from figure 1 up to figures 25–27.

A survey of the *Bolivinoides* forms belonging to this developmental sequence in other regions of the world has led me to the conclusion that, in all cases in which it is certain that the tests belong to this sequence, the number of pustules can be used to identify the age of the sediments in the following manner:

Uppermost Maestrichtian	7–9
Lower upper Maestrichtian	6–7
Middle Maestrichtian	6
Lowermost Maestrichtian	5
Upper Campanian	3–4
Lower Campanian	2–3

Dr. Edgell informs me that the same sequence is also found in Australia. I have found that it occurs in northwestern and southern Germany, in England, in the Netherlands, and in France. In Israel, according to Reiss (1954), a quite different sequence of *Bolivinoides* species is found (*Bolivinoides angulata – decorata* – cf. *miliaris – draco – dorreeni*). There also the number of pustules increases, but in a somewhat different way. The form identified by Reiss as *Bolivinoides decorata* is not the same as that of northwestern Europe; it is possible that intermittent invasions now and then produced types in northwestern Europe that were derived from these Tethys forms, since *Bolivinoides miliaris*, *Bolivinoides*

draco, and *Bolivinoides dorreeni* are found, although seldom in a continuous series. In Belgium, the Netherlands, and France, *Bolivinoides draco* is found alone in a single bed that separates the lower from the upper Maestrichtian. Other tropical forms also occur in the same bed. In northwestern Germany, *Bolivinoides miliaris* and *Bolivinoides draco* are somewhat more common, but do not have exactly the same geologic distribution as they do in Israel. Moreover, *Bolivinoides dorreeni* occurs in the *Pseudotextularia* zone (uppermost Maestrichtian) in northwestern Germany and Scandinavia, and then only in a single horizon. These occurrences seem to be a result of invasions of warmer water. They are very important for stratigraphic purposes, but the typical sequence of the larger group of *Bolivinoides* in northwestern Europe seems to be the evolutionary sequence from *Bolivinoides strigillata* to *Bolivinoides gigantea*. Detailed chronology is possible only with such a continuous sequence of changing forms.

REFERENCES

CALEMBERT, L.
1957 – *Le problème de l'étage Maastrichtien, en Belgique et dans les territoires limitrophes*. Acad. Roy. Belgique, Cl. Sci., Bull., ser. 5, vol. 43, no. 4, pp. 284–298.

HILTERMANN, M., AND KOCH, W.
1950 – *Taxonomie und Vertikalverbreitung von Bolivinoides-Arten im Senon Nordwestdeutschlands*. Geol. Jahrb., vol. 64, pp. 595–632.

HOFKER, J.
1957 – *Geologische Chronologie und die Evolution von Foraminiferen-Arten*. Neues Jahrb. Geol. Pal., pp. 338–342.

REISS, Z.
1954 – *Upper Cretaceous and Lower Tertiary Bolivinoides from Israel*. Cushman Found. Foram. Res., Contr., vol. 5, pp. 154–164.

EXPLANATION OF PLATES

All figures × 65. The number of pustules is given above each figure in Roman numerals.

PLATE 1

1–2 *Bolivinoides strigillata* (Chapman)
Craie de Saint Vaast, near Mons, Belgium.

3–4 *Bolivinoides decorata* (Jones)
Craie de Trivières, Hofker sample 581, Harmignies, Belgium.

5–6 *Bolivinoides decorata* (Jones)
Craie d'Obourg, Hofker sample 589, Harmignies, Belgium.

7 *Bolivinoides decorata* (Jones)
Top of the Craie d'Obourg, Hofker sample 555, Harmignies, Belgium.

8–9 *Bolivinoides decorata* (Jones)
Craie de Nouvelles, Hofker sample 562, Harmignies, Belgium.

10 *Bolivinoides decorata* (Jones)
Top of the Craie de Nouvelles, Hofker sample 569, Harmignies, Belgium.

11–13 *Bolivinoides australis* Edgell
Base of the Craie de Spiennes, Hofker sample 577, Harmignies, Belgium.

14 *Bolivinoides australis* Edgell
Top of the Craie de Spiennes, Hofker sample 579, Harmignies, Belgium.

15–16 *Bolivinoides australis* Edgell
Base of the Craie grise, Hofker sample 231, Hallembaye, Belgium.

17 *Bolivinoides australis* Edgell
Craie grise, Hofker sample 237, Hallembaye, Belgium.

PLATE 2

18 *Bolivinoides australis* Edgell
Craie grise, Hofker sample 240, Hallembaye, Belgium.

19 *Bolivinoides australis* Edgell
Craie tigre, Hofker sample 244, Hallembaye, Belgium.

20 *Bolivinoides australis* Edgell
Craie tigre, Hofker sample 245, Hallembaye, Belgium.

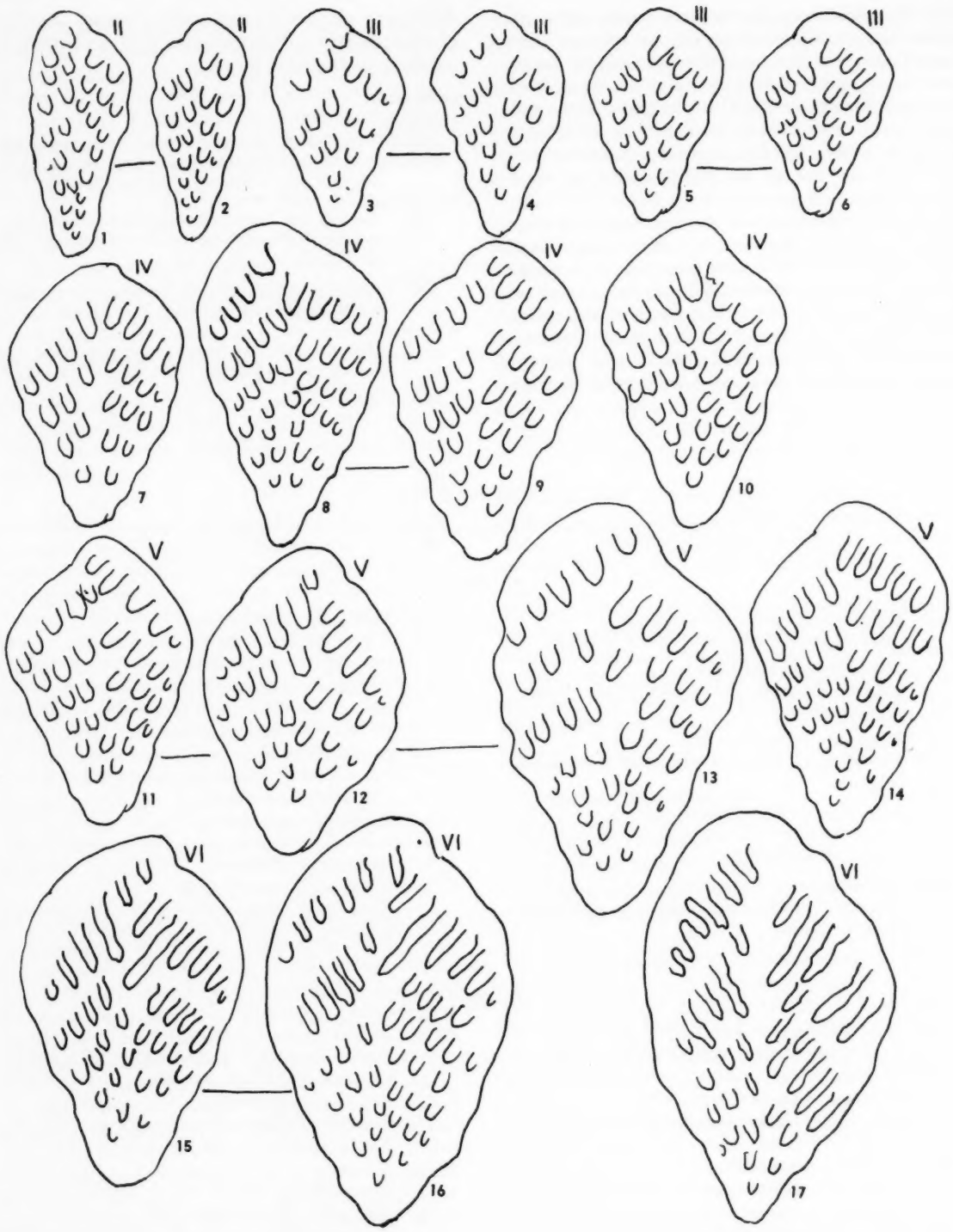
21 *Bolivinoides australis* Edgell
Top of the Craie tigre, Hallembaye, Belgium.

22–23 *Bolivinoides australis* Edgell
Craie phosphatée, Hofker sample 607, Carrière Liénard, near Mons, Belgium.

24 *Bolivinoides gigantea* Hiltermann and Koch
Base of the Tuffeau de Saint Symphorien, Carrière André (Caillaux), near Mons, Belgium.

25–26 *Bolivinoides gigantea* Hiltermann and Koch
Craie tuffoide, Petit Lannaye, Belgium.

27 *Bolivinoides gigantea* Hiltermann and Koch
Craie tuffoide, at a depth of 124 meters in a boring at the Carrière de Glons, Belgium.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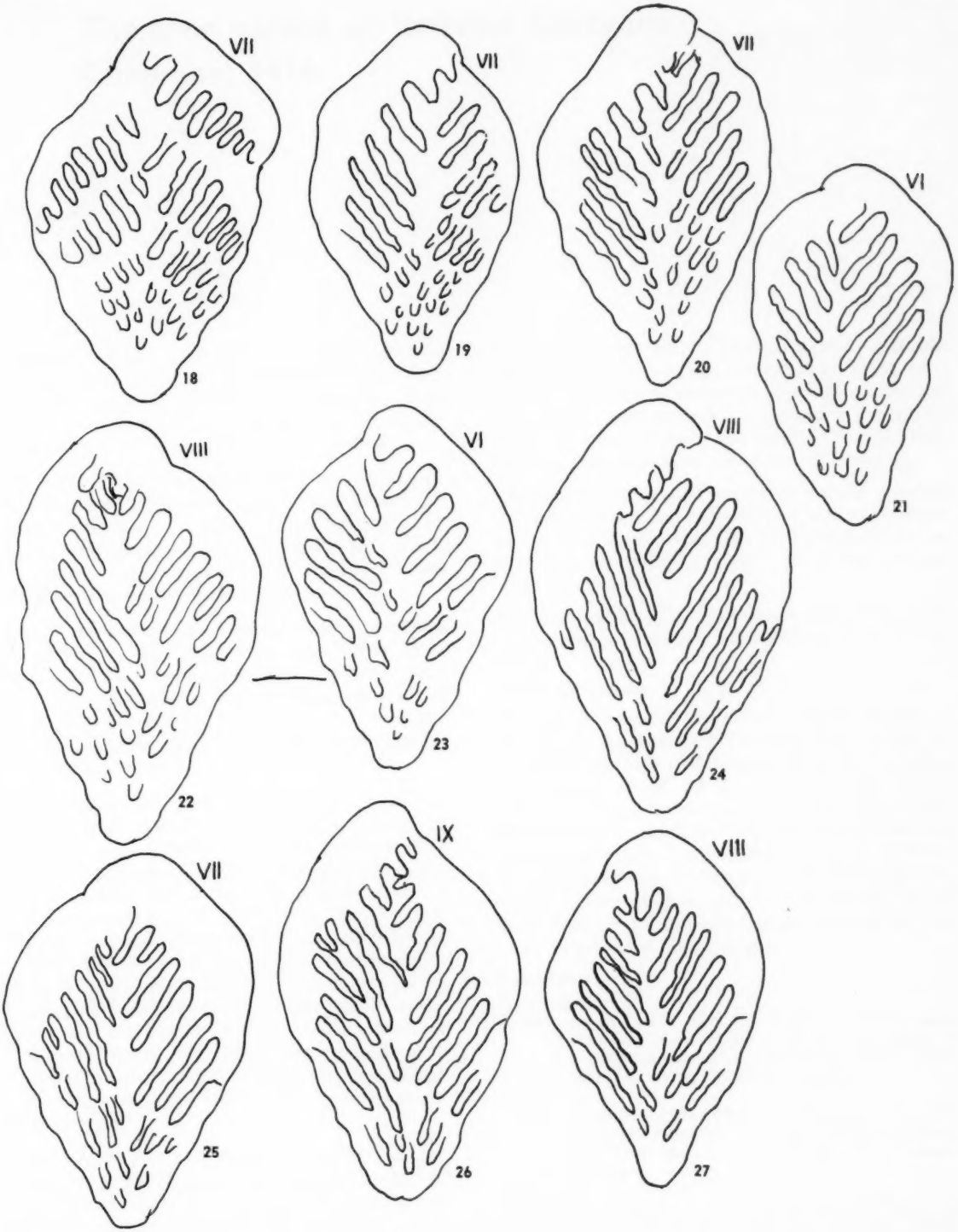
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The true nature of Bolivina hentyana Chapman, 1916

D. GRAHAM JENKINS
University College of Wales
Aberystwyth, Wales

Chapman (1916) (see also Cushman, 1937)described and figured the form *Bolivina hentyana* from the Red Limestone, Grange Burn, Victoria, Australia. These beds are considered to be equivalent to the Batesford limestone, which is Middle Miocene in age.

In March, 1957, whilst working for the Bureau of Mineral Resources, Canberra, the author visited the National Museum of Victoria at Melbourne. The holotype of *Bolivina hentyana* was found to be a small, flat, costate echinoid spine. This conclusion is based upon the observations discussed below.

An x-ray photograph shows no internal chambering (see text-fig. 2). The thigh-bone-shaped light axial area is due to the irregular deposition of iron oxide in a lumen. A corresponding structure is seen in sections of similar echinoid spines obtained from the type locality, which were cut parallel to their plane of flattening (see text-fig. 3).

It is a well known fact that echinoid spines are formed of single crystals of calcite, elongated in the direction of the C-axis. When the sections were observed in polarised light, they extinguished in the axis of elongation and at right angles to this. Similar extinction positions were obtained in the holotype at its proximal end, where it is thinnest. Members of the family Bolivinidae have a radiate wall structure in polarised light, quite different from this structure (Wood, 1949). Calcite cleavages are visible in the sections, and can be seen in the top left-hand corner of the x-ray photograph. The chamber divisions in the type figure (see text-fig. 1) are probably cleavage planes, although in the type specimen they are not clearly defined.

Professor H. B. Fell, of Victoria University College, Wellington, New Zealand, has examined echinoid spines obtained from the type locality. In a private communication he has made the following observations:

"The type illustrated in Chapman's paper looks like the miliary (or perhaps scrobicular) spine of a cidarid, and in particular resembles *Phyllocanthus* and *Prionocidaris*; both genera are present in beds from which it comes. I have not handled the holotype and can judge only from the printed illustration.

"The specimens you forwarded to me are certainly the scrobicular spines of a cidarid, either *Phyllocanthus* or *Prionocidaris*, probably the former. I have no hesitation in confirming your opinion that they are echinoid spines."

For these reasons, *Bolivina hentyana* Chapman, 1916, can no longer be considered to belong to the foraminifera.

ACKNOWLEDGMENTS

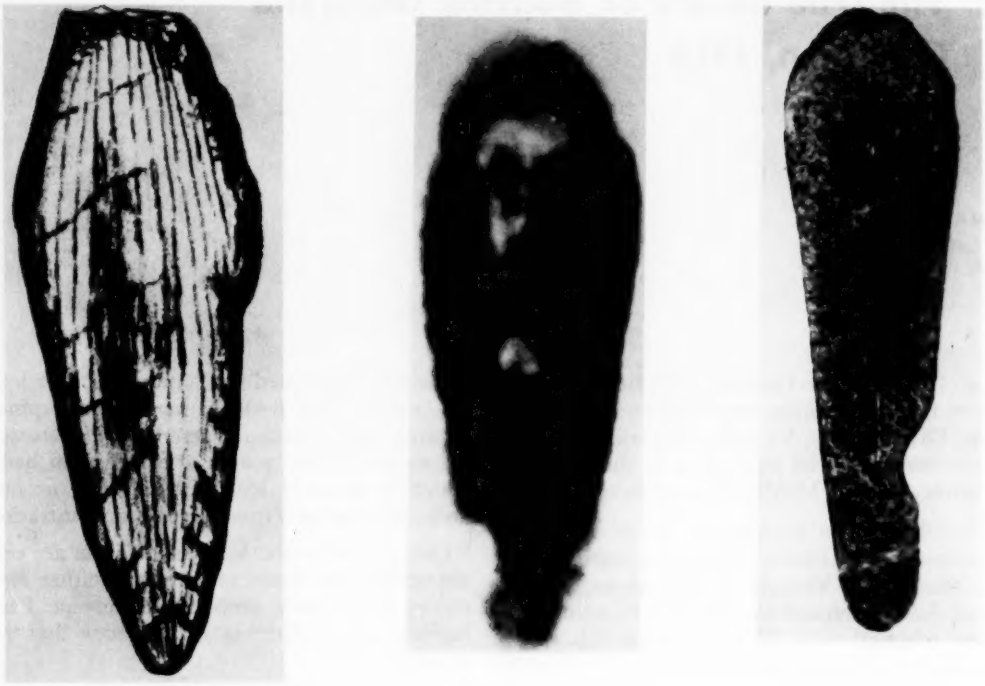
The writer wishes to express his sincere thanks to Dr. H. G. Raggatt and Professor Alan Wood for arranging hist visit to Australia. He is also indebted to Professor Wood for his guidance and helpful criticisms during the preparation of this paper. The writer wishes to thank the following persons for their cooperation: Miss Irene Crespin, D. J. Belford, P. J. Jones, Dr. M. F. Glaessner, Dr. N. Ludbrook, and A. Carter. The writer's thanks are also due to E. D. Gill, who supplied topotype material and an x-ray negative of the holotype.

BIBLIOGRAPHY

CHAPMAN, F.
1916 – *On some smaller fossils from the Red Limestone at Grange Burn, near Hamilton, with a note on a new species of Bolivina.* Victorian Nat., Melbourne, vol. 32 (1915–1916), no. 10, pp. 145–146, 1 text-fig.

CUSHMAN, J. A.
1937 – *A monograph of the subfamily Virgulininae of the foraminiferal family Buliminidae.* Cushman Lab. Foram. Res., Spec. Publ. no. 9, p. 180, pl. 21, figs. 6–8 [*Loxostomum hentyanum*].

WOOD, A.
1949 – *The structure of the wall of the test in the foraminifera; its value in classification.* Geol. Soc. London, Quart. Jour., vol. 104, pt. 2, pp. 229–255, pls. 13–15.



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TEXT-FIGURES 1–3

1–2, *Bolivina hentyana* Chapman, 1916, from the Red Limestone, Grange Burn, Victoria, Australia: 1, Chapman's type figure, × 24; 2, x-ray photograph of the holotype, × 23; 3, longitudinal section of an echinoid spine from the type area, cut parallel to its plane of flattening (polarised light), × 15.

news reports

INDIA

S. R. N. RAO

Assam Oil Co. Ltd., Digboi

Most of the work has been of a routine nature, pertaining to the examination of surface samples from the Khasi and Garo Hills and of subsurface Barail samples from Nahorkatiya. Abundant calcareous algae, which may be of some assistance in local correlation, occur in the Eocene of the Khasi Hills, particularly in the Lakadong beds (Paleocene). Most of these algae belong to the Corallinaceae, but some Dasycladaceae are also present. The foraminiferal fauna is most interesting, and *Alveolina primaeva* Reichel, a characteristic Paleocene form in Europe, has recently been identified in limestones of the Lakadong beds. Further study of this fauna is in progress. The possibilities of palynology as a means of correlation within the Barails are being investigated further.

Muslim University, Aligarh

P. N. Ganju has published a paper entitled "The microstructure of coals from the Jangalgali and Kalkot areas in the Jammu Province" (Indian Acad. Sci., Proc., vol. 44, 1956, pp. 30-37). The paper deals with a detailed study of the petrological constituents of coals from the Ladda and Kalkot coal fields. Thin sections and polished blocks of coal were examined microscopically. As a result of this study, it has been found that the Jangalgali coals are composed almost entirely of woody tissues that do not show any well preserved plant structure. Sclerotia resembling *Sclerotites brandonianus* occur in large numbers. Teleutospores occur in various forms. Siderite matter is quite abundant. The Kalkot coals appear distinctly clarainy, showing thin strips of vitrain in a groundmass which is largely composed of finely disseminated fusain material. Balls of fusain are conspicuous. Mineral matter composed largely of siderite and ankerite is widely distributed in the groundmass. Fungal spores are less abundant.

The microscopic constituents reveal tha the coals have generally undergone much compression and folding, the Jangalgali coals more so than those of Kalkot. In the nature of their fungal organisms, these coals appear to resemble some Tertiary coals of Assam.

Ganju has another paper ready dealing with the nature of microfragmental constituents in the coals of the Rampur coal field. The microfragmental material includes spore exines in abundance. The megaspore exines occur in a variety of forms showing varied surface ornamentation, and some seams show distinct types of these exines. At least five types of exines have been recognised, four of which are restricted to the seam being worked in the Orient (Birla) colliery. Vitrinite and fusinite bands are scarce, although in some durains these constituents occur in a fine state of preservation. In their characters these coals are quite distinct from the coals of the Damodar Valley coal fields and also from those of the Talchir coal fields.

Birbal Sahni Institute of Palaeobotany, Lucknow

Professor R. Potonié, Professor of Coal Petrology at the University of Bonn, West Germany, joined the Institute as a Visiting Scientist in November, 1957. He is expected to stay here until the end of March, 1958. He is training the personnel of the Department in the study of the Sporae dispersae of the Lower Gondwana coal and the correlation of the coal seams.

D. C. Bharadwaj has published a paper (The Palaeobotanist, vol. 4, pp. 114-149) entitled "The spore genera from the Upper Carboniferous coals of the Saar and their value in stratigraphical studies." The paper describes five new genera, and also includes detailed descriptions of six other recently proposed genera. Stratigraphic subdivisions of the Upper Carboniferous succession in the Saar are suggested on the basis of variation in the microfloral assemblages of the successive periods. The vertical distributions of the Sporae dispersae, as well as those of the megaflora, are compared and are shown to be similar. The Westphalian D of the Saar is found to comprise the combined zones of *Palaeoweichselia defrancei* and *Neuropteris orata*. The Stephanian of the Saar consists of two subdivisions, the lower Stephanian, lacking Westphalian influence, and the upper Stephanian, with pronounced Westphalian character. Bharadwaj has also completed papers on *Asterotheca meriani* (Brongniart) Stur and its spores; on the Sporae dispersae of the Upper Carboniferous – lower Rotliegend succession in Pfalz; and on the phylogeny of Palaeozoic Sporae dispersae.

Work is still in progress on microspores and cuticles from thirty-seven samples of coal from Lorraine, France. Hari Pal Singh has completed a paper on spores from the Jurassic coal of Austria.

S. C. D. Sah and G. K. B. Navale are working on the Sporae dispersae of the Barren Measures and Neyvelli lignite, respectively. Sah has published a paper (The Palaeobotanist, vol. 4, 1955, pp. 60–72) entitled "Plant microfossils from the Jurassic shale of Salt Range, West Punjab

(Pakistan)." The paper describes a rich variety of microfossils, including several kinds of spores, both winged and unwinged, fragments of wood, and several cuticular pieces. The spores are mostly pteridophytic and coniferous, cycadophytic grains being rare. The microflora as a whole suggests a Middle Jurassic age for the variegated shale.

M. N. Bose has examined the microfloras of more than fifty samples from the Belgian Congo and of one sample from Baffin Island. Nair has studied the pollen content of the early Pleistocene deposits of Kashmir.

Vishnu Mittre has published a paper (The Palaeobotanist, vol. 4, pp. 151–152) entitled "*Sporojuglandoidites jurassicus* gen. et sp. nov., a sporomorph from the Jurassic of the Rajmahal Hills, Behar." The new sporomorph is distinguished by the presence of foraminoid apertures on its body, a character not met with in any plant group except angiosperms. In general characters it seems to resemble juglandioid grains.

Lucknow University

A. R. Rao has published a paper on algal remains from the Tertiary lignites of Palana (Eocene), Bikaner (Current Science, vol. 26, no. 6, p. 177). He has described new microfossils which include some unicellular blue-green algae comparable to *Synechocystis*, organisms that look like *Euglena*, fragments of *Ulothrix*-like filaments, and a number of unbranched filamentous algae referred to a new form-genus, *Oedogoniites*, classified under the Oedogoniales (Chlorophyceae) and designated *Oedogoniites palanensis*.

B. S. Tewari is continuing his work on the microfossils of the Tertiary rocks of Kutch. He has a paper in press entitled "The geology and stratigraphy of Waior, Kutch, western India." S. B. Bhatia and I. P. Saxena have published a paper (Cushman Found. Foram. Res., Contr., vol. 8, pt. 4, pp. 146–148) entitled "Occurrence of the genus *Hyperammina* in the marine Permo-Carboniferous beds at Umaria, central India." The foraminiferal genus *Hyperammina* is recorded for the first time from Umaria. The genus is represented by two species, *Hyperammina gracilis* Waters and *Hyperammina* aff. *H. elongata* Brady var. *clavatula* Howchin. S. B. Bhatia and N. K. Mandwal have a paper in press entitled "Smaller foraminifera from the Agate conglomerates (Burdigalian) of the Surat-Broach area, western India." Twenty-six species and varieties are illustrated and described.

Mysore University

L. Rama Rao, in a paper entitled "Fossil foraminifera from the Cretaceous rocks of South India" (Indian Acad. Sci., Proc., vol. 45, pp. 263–281), has reviewed our present knowledge of the Cretaceous orbitoids occurring in the Ariyalur area.

National Institute of Sciences of India, New Delhi

In a series of publications entitled "Progress of science in India (1938–1950)," which has recently been brought out by the Institute, Section VIII, Geology (pp. 1–138), is under the editorship of M. S. Krishnan. The review under Stratigraphy, Palaeontology and Palaeobotany includes an excellent account of progress in micropalaeontology.

S. R. N. Rao
Department of Geology
University of Lucknow

UNITED STATES–EAST-CENTRAL

ROBERT V. KESLING

Ohio State University

Mildred Marple is continuing her studies of Pennsylvanian microfaunas of Ohio. Charles H. Summerson has completed papers on Devonian arenaceous foraminifera and Pennsylvanian holothurians, and is now working on other aspects of the Kentucky Pennsylvanian microfaunas.

Walter Sweet writes that he and three of his students, Caroline Turco, Lorna Wilkie, and Earl Warner, have a manuscript nearly completed on the conodont faunas of the Eden group in southwestern Ohio. This will be submitted to the Journal of Paleontology very soon. This summer they will begin field work on Maysville microfaunas, and hope to do the conodonts first and the ostracodes and scolecodonts later.

Ohio Geological Survey

George Denton is studying the plant microfossil assemblages in the coal beds and associated strata in Ohio. He will present a paper on the Homewood-Tionesta assemblages at the Paleobotanical Section of the American Botanical Society, which meets at Bloomington, Indiana, in August.

Pauline Smyth continues her investigations of fusulinids in the Pennsylvanian limestones of Ohio. A paper on this subject appeared in the September, 1957, issue of the Ohio Journal of Science.

United States Geological Survey
Coal Geology Laboratory, Columbus, Ohio

From J. M. Schopf we learn that he is busy on spore studies on Alabama and Kentucky coal measures. He has found pollen grains of "Permian" aspect in the Pennsylvanian Paradox salt deposits in Utah. Several assemblages dominated by *Tasmanites* spp. from the western United States are also being examined. Dr. Schopf states, "The demand for persons with spore and pollen experience is great, and I am carrying on with a minimum staff."

University of Dayton

Dr. H. N. Coryell reports that two micropaleontology courses, covering a full year on foraminifera, ostracodes, and other microfossils, have

been added to the Geology Department curriculum. He is teaching both courses, using well samples from petroleum exploration.

University of Cincinnati

Kenneth E. Caster says that Augustus Armstrong has a paper about ready for press on New Mexico endothyrids and their stratigraphic significance. James E. Conkin's Ph.D. dissertation on Mississippian arenaceous foraminifera is well advanced.

An extensive shale-washing project, carried out mainly by two volunteer workers, William Deak and Joseph Stocker, Jr., on a bed in the lower Richmondian of Cincinnati, is yielding "wonderful ostracode materials, thousands of carpoid echinoderm plates which reveal many new structures, and a great variety of other small fragmental material of great interest."

Notre Dame University

R. C. Gutschick states, "I am continuing work on the very interesting Rockford limestone microfauna and expect to have papers out shortly on the arenaceous foraminifera, holothurian sclerites, ostracodes, and microcrinoids. At the same time I am working on a companion study of the arenaceous foraminifera from the Welden limestone of Oklahoma. The ostracode studies are being done with Dr. Winkler of the Department." Dr. Gutschick hopes eventually to study the entire fauna of the Rockford limestone, which occurs in limited outcrops in northern Indiana.

University of Illinois

Harold W. Scott is in California, but his secretary replies that he is working on Tertiary ostracodes and foraminifera from Pakistan, mostly Eocene and Miocene faunas.

Michigan State University

Mrs. Robert Smith sends the following items of interest: Study of fossil foraminifera, ostracodes, Bryozoa, and other microfossils has been offered in the curriculum of M.S.U. at both the undergraduate and graduate levels since about 1945. From now on, these studies will be taught only at the graduate level. A master's thesis, "Ostracods from the Beebe School shale," is being completed, and will add to our knowledge of the Middle Devonian faunas of Michigan. Investigations of Chitinozoa and conodonts from Ordovician well cores in the Michigan Basin are under way.

University of Michigan

Students in the advanced micropaleontology class of 1957 and your correspondent have published a short paper on a new beyrichiid genus bearing a strong resemblance to *Chilobolbina* (Jour. Pal., vol. 32, no. 1, 1958). Other papers from the staff of the Museum of Paleontology include "*Dolichoscapha*, a new beyrichiid ostracod genus," by Kesling and Ehlers *(ibid.)*, and "A new and unusual species of the ostracod genus *Herrmannina* from the Middle Silurian Hendricks dolomite of Michigan," by Kesling (Michigan, Univ., Mus. Pal., Contr., vol. 14, no. 7, 1958). Other papers are in press. The advanced micropaleontology class of 1958 is working on the quasillitid ostracode fauna of a Middle Devonian formation. This study will soon be completed and readied for publication.

Illinois Geological Survey

Mrs. Marcia R. Winslow has almost completed her investigation of megaspores from the Upper Mississippian and Pennsylvanian coal beds of Illinois. This paper should be in print some time during 1959. Fred W. Cropp has started an investigation of the small spores of Tennessee coal beds for his Ph.D. thesis, to be submitted at the University of Illinois. This should be completed during 1959.

Robert Kosanke has been working up the small-spore content of a number of Illinois coal beds, samples of which have just recently been made available. The small-spore content of these beds has not been previously reported. It is expected that his work will be completed late in 1959. Dr. Kosanke is also working on a literature review of palynological papers published between 1949 and 1957.

Indiana University

T. G. Perry is continuing his studies of the Brownsport (Middle Silurian) bryozoan fauna of west-central Tennessee, and has received a research grant for this work from the Geological Society of America. A report of this investigation will probably be given at the November meeting of the G.S.A.

Professor Perry and D. E. Hattin have nearly completed a study of structural changes during astogeny of Paleozoic cyclostomatous Bryozoa. "Unlike trepostomatous bryozoans, features of generic and specific importance display very little change during the observed development of the zoarium," Professor Perry writes. He plans to publish his results as soon as photomicrographs are taken.

Dr. J. J. Galloway is engaged in further work on stromatoporoids. Dr. Guennel is still studying spores, but has no papers in press. Dr. David G. Frey, Professor of Zoology, has a paper entitled "The taxonomic and phylogenetic significance of the head pores of the Chydoridae (Cladocera)" in press, to be published soon in the Internationale Revue der gesamten Hydrobiologie und Hydrographie. He has a late glacial fauna taken from a 1½-meter varved stratum in the Schleinsee, a lake in southern Germany.

Indiana Geological Survey

R. H. Shaver's paper mentioned in the previous news report will be published very soon in the American Midland Naturalist. He is now undertaking a project on the micropaleontology of the Lower Pennsylvanian Morrow and Atoka formations. Dr. M. L. Thompson is working on the fusulinids and Dr. Shaver on the ostracodes from the Lower marine zones in Indiana,

Kentucky, and Illinois. The first paper from this project comprises parts on fusulinids by Thompson and Riggs and on ostracodes by Shaver, and includes Morrow-Atoka faunas from a few sections in Kentucky. Some work remains to be done on this paper before publication.

ROBERT V. KESLING
University of Michigan
Ann Arbor, Michigan

U. S. S. R.

During a very short visit to Russia, from October 30 to November 12, 1957, on the invitation of the Russian "Society for Cultural Relations," I had the welcome opportunity of meeting a number of micropaleontologists. The short time, part of which was spent on lectures and discussions of geologic problems, made it impossible to obtain a comprehensive view of the enormous scope of current work, and I cannot claim to be able to give a balanced picture. Personal contacts, however, are so rare that even this incomplete picture may be of some interest.

My first visit was a very brief one to the Paleontological Institute of the Academy of Sciences (Moscow 71, Bol. Kaluzhskaya 33, Director Professor Y. A. Orlov), where work on fusulinids is being carried out. After that, I visited the Geological Institute of the Academy of Sciences (Director N. S. Shatskii, Moscow B-17, Pyzhevskii Per. 7), where I heard with regret that D. M. Rauser-Chernoussova, the well known worker on Paleozoic foraminifera and one of the leaders in Russian micropaleontology for the past twenty-five years, was ill after a bout of influenza. In 1956, she published a most interesting 85-page symposium under the title "Micropaleontological problems" (Voprosi mikropaleontologii), and a second volume is in preparation.

Dr. E. A. Reitlinger is now studying Permian foraminifera, and V. G. Morozova is working on Cretaceous and Tertiary microfaunas. Her paper on "The superfamily of foraminifera, Globigerinidea nov. superf., and some of its representatives" has just appeared in the Doklady Akad. Nauk S.S.S.R., vol. 114, no. 5, pp. 1109–1112. Sophia N. Naumova is continuing her well known studies on Paleozoic spores.

In the splendid new main building of Moscow University, a micropaleontological laboratory under the direction of Nina J. Sladkova is attached to the Faculty of Geology. There is also a palynology laboratory.

Many other micropaleontological laboratories are operating in Moscow, at the Institute of Oceanology, the Institute of Petroleum, the Moscow District Geological Survey Office, and others.

In Leningrad I visited the Petroleum Geology Research Institute (V.N.I. G.R.I., Liteinyi Prospect 39). The head of the micropaleontology laboratory, Dr. Nina N. Subbotina, was at that time in India on consulting work. Her deputy, Dr. N. A. Voloshinova, was in Kamchatka. L. P. Grozdilova is working on late Paleozoic smaller foraminifera; Lydia G. Dain is studying the Polymorphinidae monographically; V. P. Vassilenko and others are working on other smaller foraminifera; M. N. Mandelstam is in charge of Ostracoda; and there is a palynological laboratory, under the direction of V. S. Malyavkina. The Institute has published seven volumes of assorted papers under the title "Microfauna of the U.S.S.R." and six splendid volumes entitled "Fossil foraminifera of the U.S.S.R.," which deserve close study. A new comprehensive treatise on foraminifera is in press as part of a forthcoming work on "Principles of paleontology" (Acad. Sci. U.S.S.R.) in many volumes. At the Zoological Institute of the Academy of Sciences, Z. G. Shchedrina is working on Recent Arctic and Antarctic foraminifera, and at the University of Leningrad (Institute of Historical Geology), Dr. A. D. Miklukho-Maklai is studying fusulinids.

My general impressions from observations and discussions are as follows: (1) The great and growing importance of palynology, particularly in connection with the study of marine sediment cores and of older rocks; (2) the brilliant detailed morphologic and biostratigraphic investigations of late Paleozoic foraminifera, and the careful indexing of observations in this field over many years, first introduced by Rauser-Chernoussova and her coworkers; (3) the wide use of index fossils in the classical sense among the smaller foraminifera of the Mesozoic and Tertiary for zoning and correlation; the practical importance and volume of this work are so great that there seems to be little time for detailed morphological investigations of the finer structures of these foraminifera, and taxonomy thus tends to be conservative; microplankton, planktonic foraminifera, and morphogenetic series are not receiving as much attention as elsewhere; (4) the frequency of meetings and conferences, enabling the numerous micropaleontologists, probably many hundreds, to keep well informed of each other's work and of advances in stratigraphy. There is of course no secrecy in this field. Publication is still slow but is improving, although the issues (1500–2000 copies) are too small for the demand. Equipment and techniques are quite up to date, technical assistance is abundant, and very capable artists are employed in every loboratory to make drawings of specimens for catalogues and publications. Photomicrography is very little used for three-dimensional objects. Laboratory space is generally insufficient and often grossly overcrowded, but this is being remedied at least in some places.

Russian workers are rightly proud of their achievements, and at the same time are all very keen to exchange material and publications with their Western colleagues. I hope that this note will help them to establish or to widen their contacts.

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